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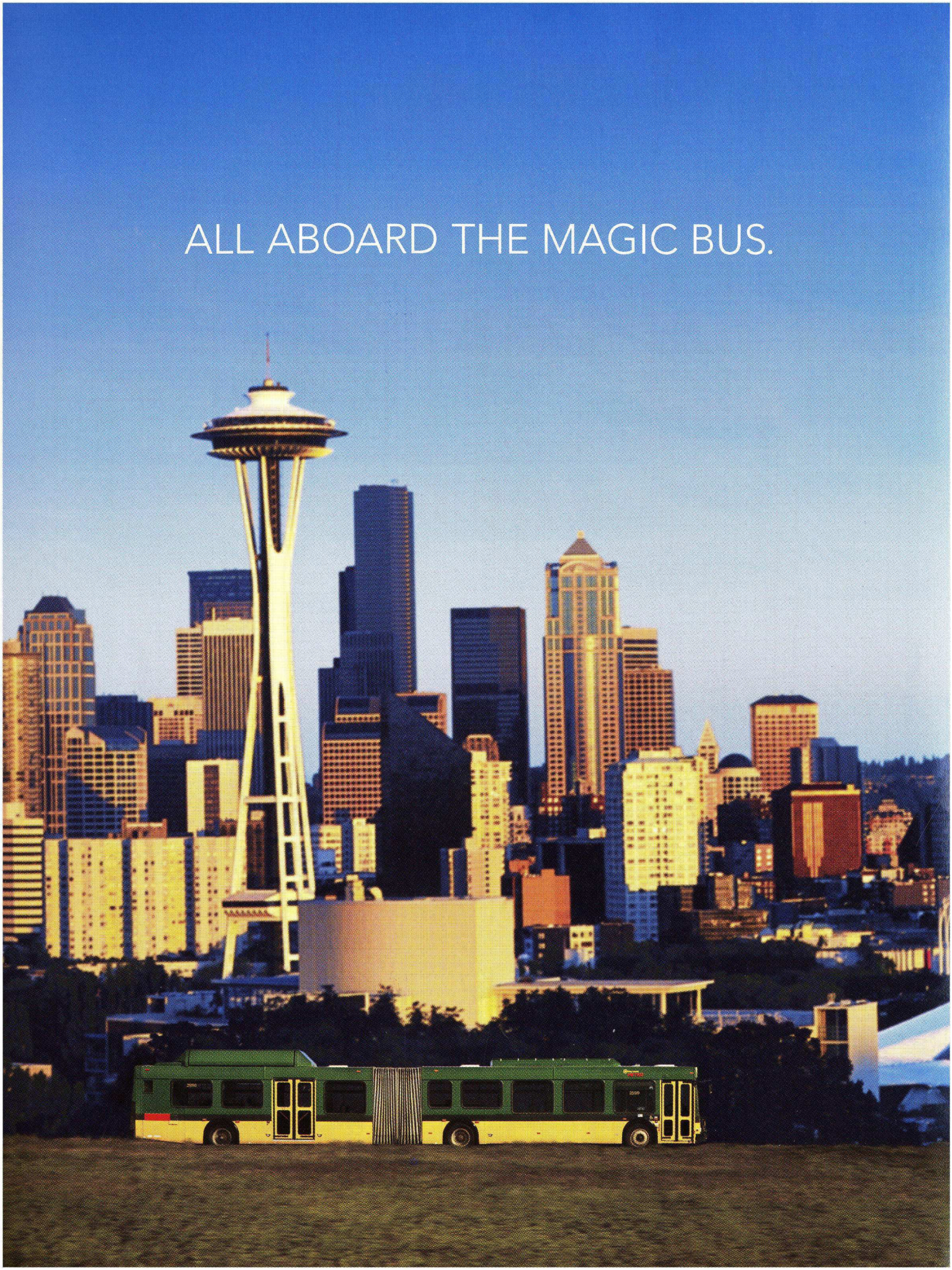
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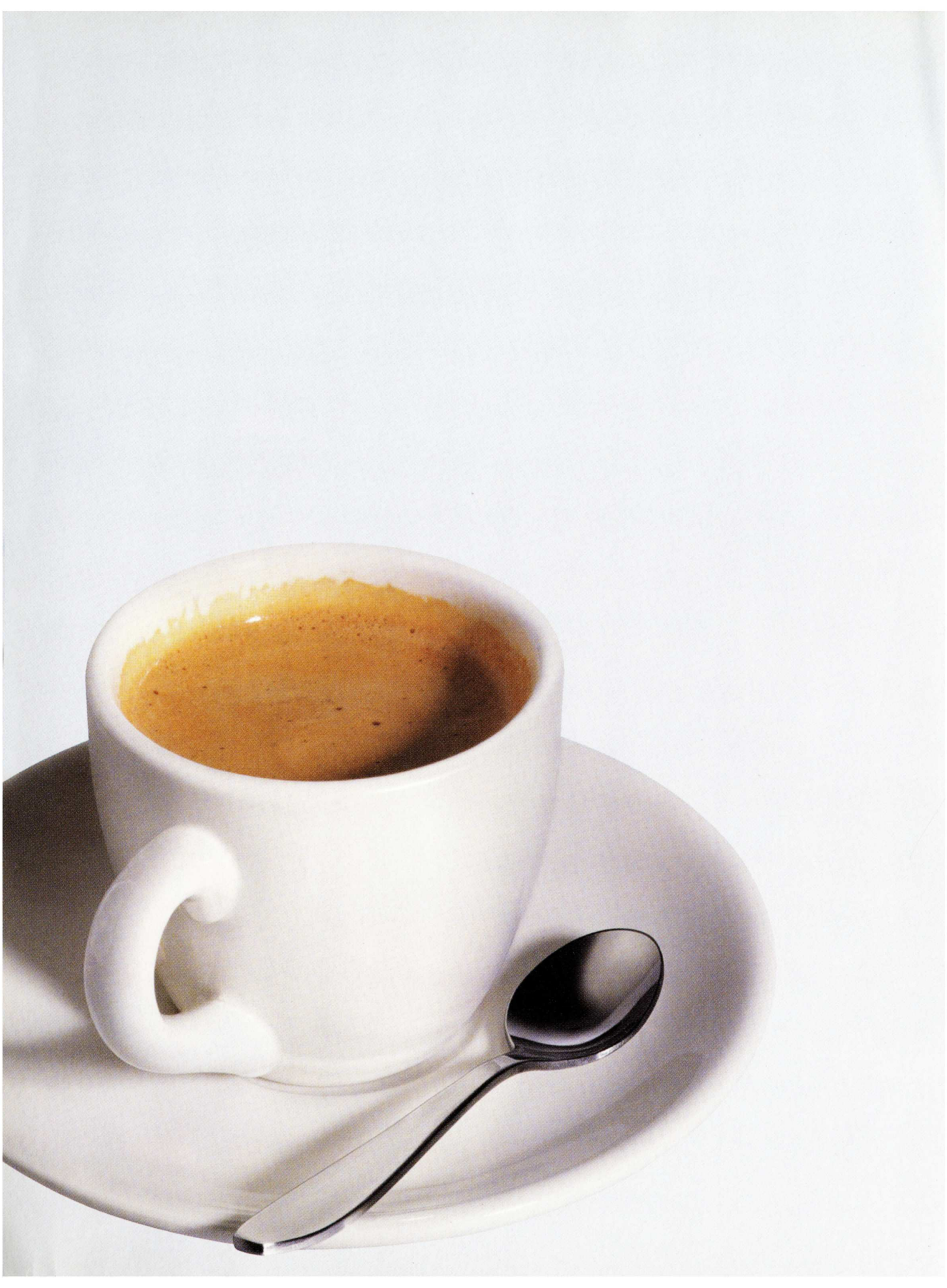
*Claims compared to a conventional diesel bus on an urban schedule.



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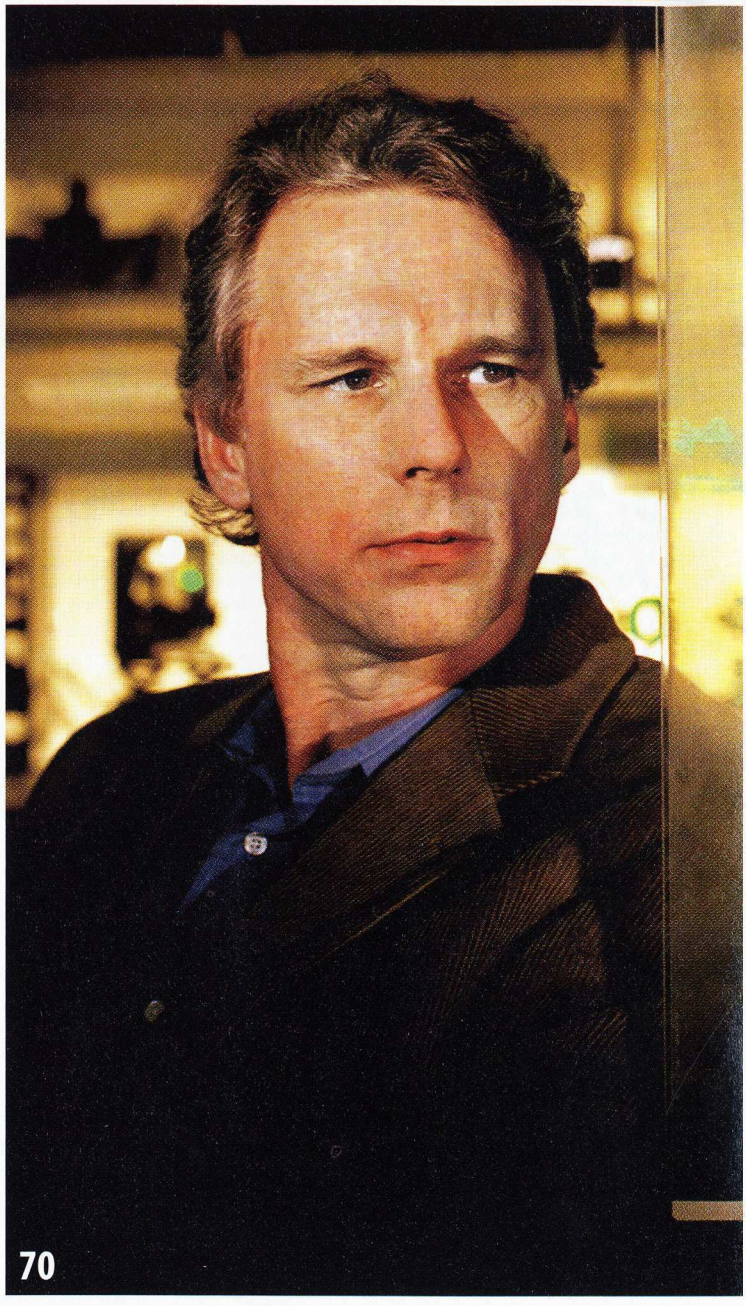
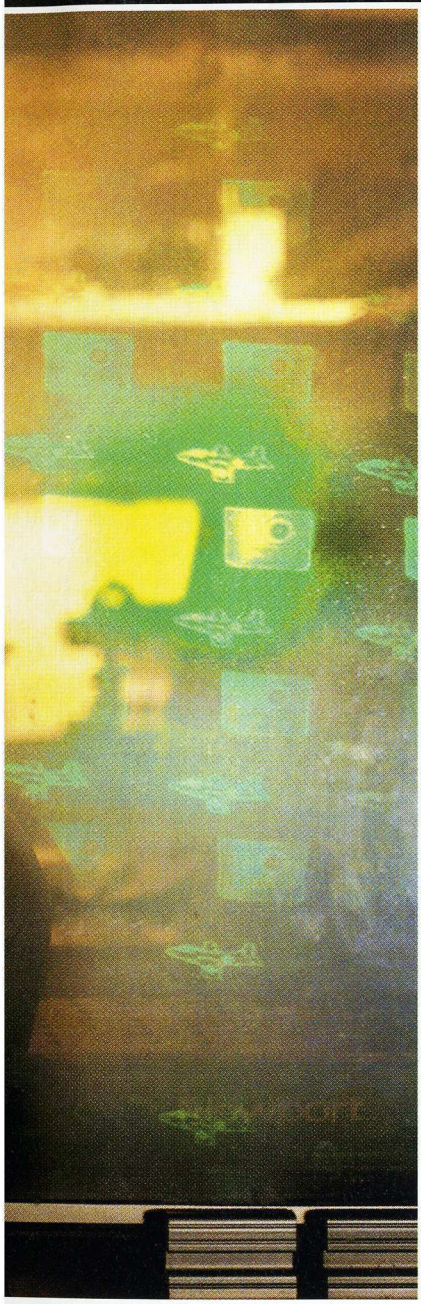
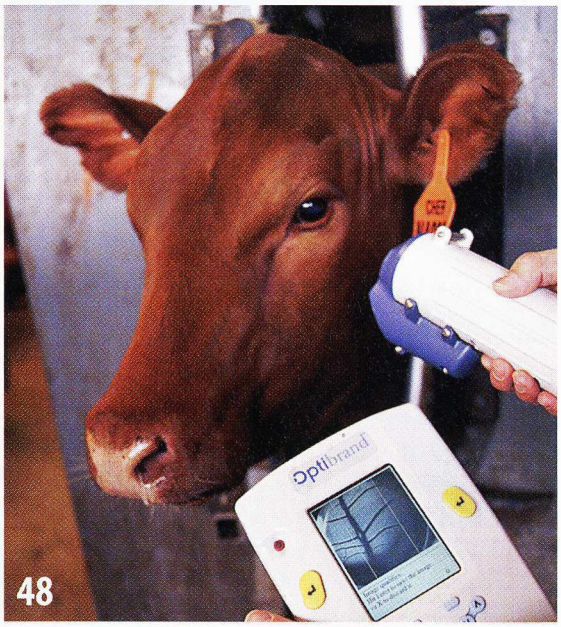


DEPARTMENTS

Technology Review
Volume 107, Number 5
June 2004

"People should pay attention to China. It is a phenomenon in every respect."—*Bill Gates, p. 35*





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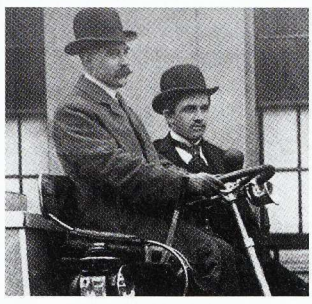

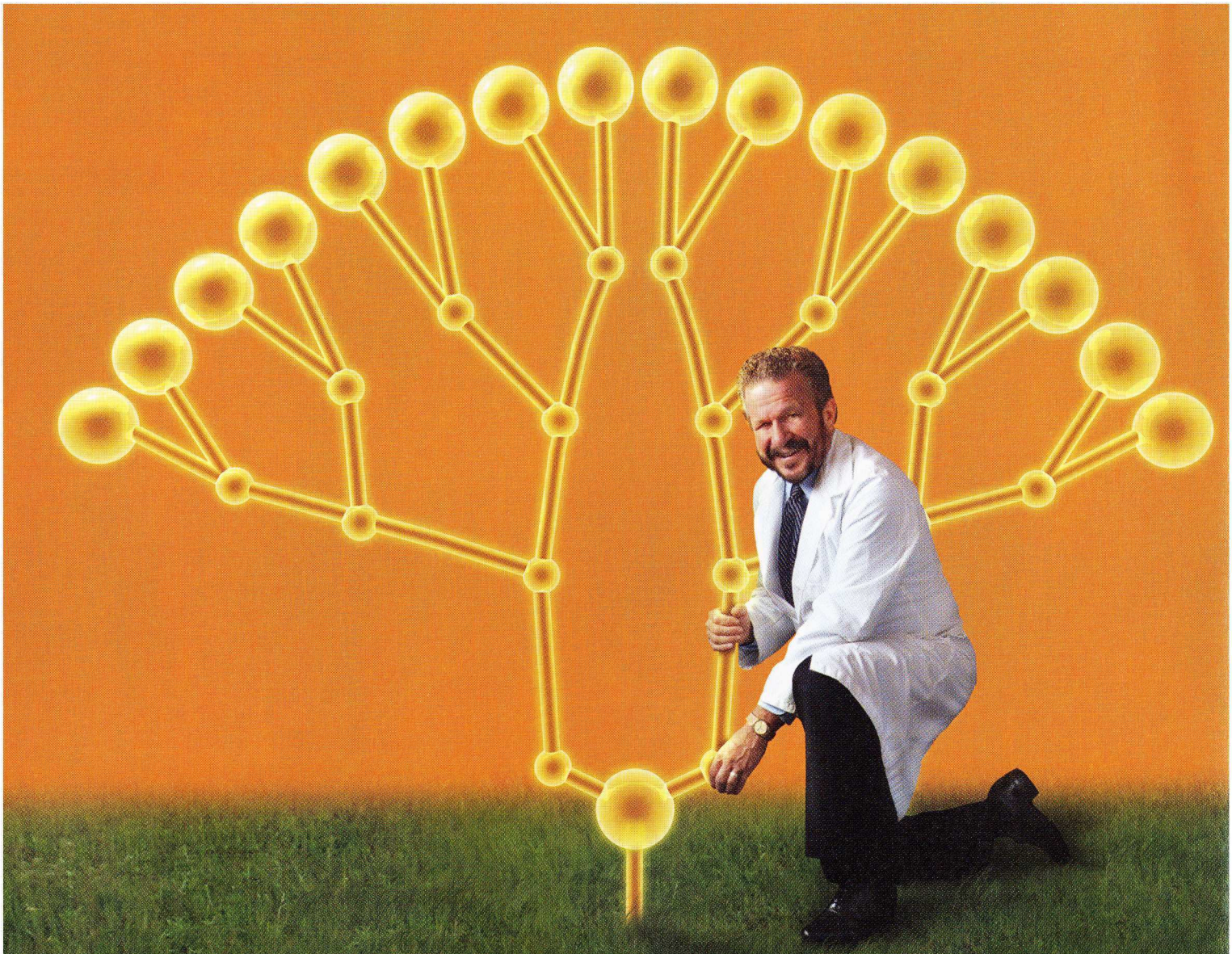

TREES INSPIRED DR. TOMALIA'S NANOTECHNOLOGY DELIVERY SYSTEMS.

HE PLANTED HIS COMPANY IN MICHIGAN.

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Insourcing

AS U.S. FIRMS MOVE MORE AND MORE MANUFACturing, customer support, and now software development jobs to lower-cost countries, outsourcing has become one of today's most controversial business trends. ■ Lost in the debate is a related idea that could be far more vital to future competitiveness: insourcing. As I use the term, this is the practice of opening operations in foreign countries, not to do current jobs more cheaply, but to generate new products and services that spur growth and create jobs. I'm particularly interested in research-and-development insourcing where firms insource foreign talent by creating labs in other countries. And a prime example of how to do this effectively can be found in this month's cover story, "The World's Hottest Computer Lab" *(p. 32)*, about Microsoft's fast-growing Beijing research center.

On the surface, Microsoft isn't doing anything new. IBM, for instance, operates research labs in China, India, Israel, Japan, and Switzerland. Scores of other tech firms, in everything from pharmaceuticals to electronics, operate R&D labs abroad.

So what's so special about Microsoft's venture? I have visited three dozen corporate research labs worldwide, many of them expatriate labs. I've studied the challenges they face, and their efforts to meet those challenges. Several things stand out about what Microsoft's doing, but all boil down to how the lab has avoided being marginalized.

First, far from their mother ships, foreign labs often become second-class citizens in their own firms. Microsoft has escaped this trap in part by investing enough in the lab (more than $80 million, 150 full-time researchers, and 200-odd interns) that it has achieved critical mass. More importantly, the Beijing operation is an epicenter for several key areas of research, including graphics and wireless multimedia. I have seen at least three foreign labs fail because they were bit players in the research areas they covered.

Even this, though, does not fully explain the Beijing lab's success in generating innovations that make it into products—some 70 in its first five years. The lab's secret sauce, I think, is that two of its former directors, Kai-Fu Lee and Ya-Qin Zhang, have been promoted to executive positions at Microsoft's headquarters in Redmond, WA. This is a huge stamp of approval, and source of motivation, for everyone at the lab. It also ensures strong ties between the lab and Microsoft's product groups. In all my visits to foreign labs, I can't remember this happening once, let alone twice.

The lab has also proved its value in China. To be a magnet for talent, a lab has to be seen by local officials and academics as a great place to send students and graduates. Through such practices as encouraging publication of papers and conducting collaborative research with universities, Microsoft seems to have passed this test.

The world is changing fast. According to a study released in February by five higher-education associations, the number of foreign students applying to American graduate programs is declining. U.S.-based technology firms like Microsoft know that to stay competitive, they must find new ways to tap that foreign talent. **Robert Buderi**

THANKS AND FAREWELL

As this issue goes to print, I will complete my second year as editor of *Technology Review*. At that time, I will step down and "reclaim" my previous position of editor at large.

I've had a great time, working with a fantastic staff, and getting to know many of you, our highly discerning readers. My new position will allow me to be more involved with the nitty-gritty of the magazine—and to dive into a new book project—but I'll still be out and about and look forward to our continued interaction. Till then…

NEXT MONTH

Japan's Wireless Wizardry
Ubiquitous computing is finally living up to its promise, at least for millions of Japanese cell-phone users. For everything from paying for the subway to opening their apartment doors, Japanese consumers are dialing into the wireless revolution.

The Age of the Ultratall Building
The world's newest "tallest building" is nearing completion in Taiwan—but could soon be dwarfed by even more gargantuan structures proposed for Shanghai and Dubai. How do you make these superbuildings safe and secure?

Solar Revolution
Imagine solar cells that could be easily and cheaply printed on the roofs of buildings or on laptop computer casings. Advances in nanotech are making them possible, and commercial versions could soon see the light of day.

Gesture Interfaces
From video games to devices to help the disabled, more and more computers are coming equipped for gesture recognition. A wave of the hand or the pointing of a finger is all it takes to communicate with this new generation of machines.

Safer Cancer Tests
A new group of simple blood tests means you might soon be able to skip the expensive and risky imaging techniques and biopsies used to spot early signs of cancer.

Robotic Super Heroes
Able to leap over tall buildings? Maybe not. But the latest versions of wearable robotics could allow soldiers, firefighters, or construction workers to carry much heavier loads, or the paralyzed to get around.

And more...

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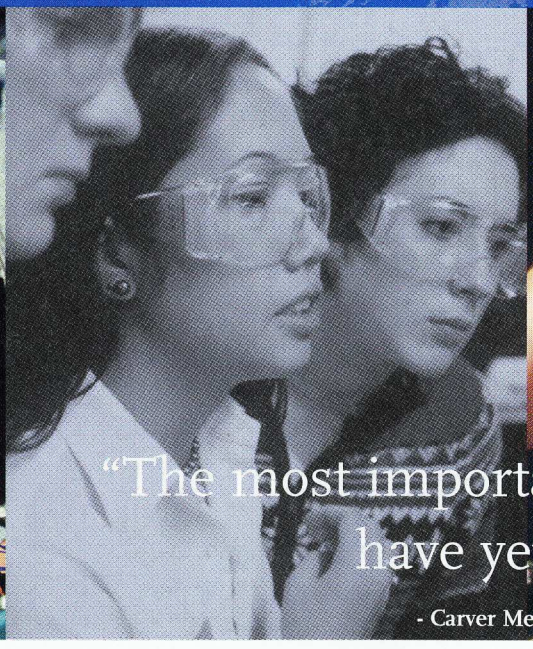

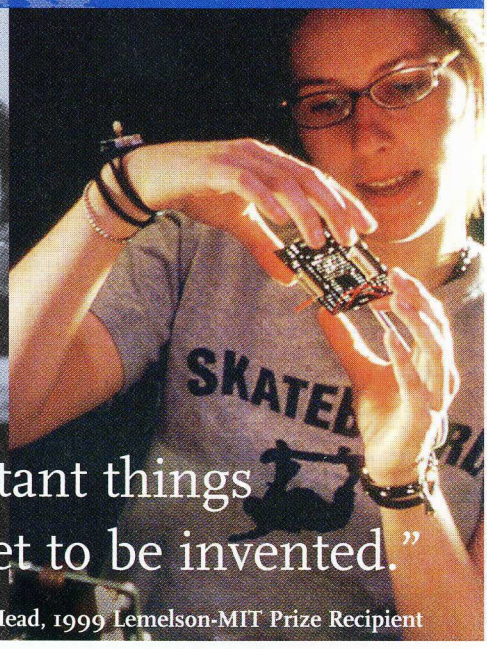

"The most important things have yet to be invented."

- Carver Mead, 1999 Lemelson-MIT Prize Recipient

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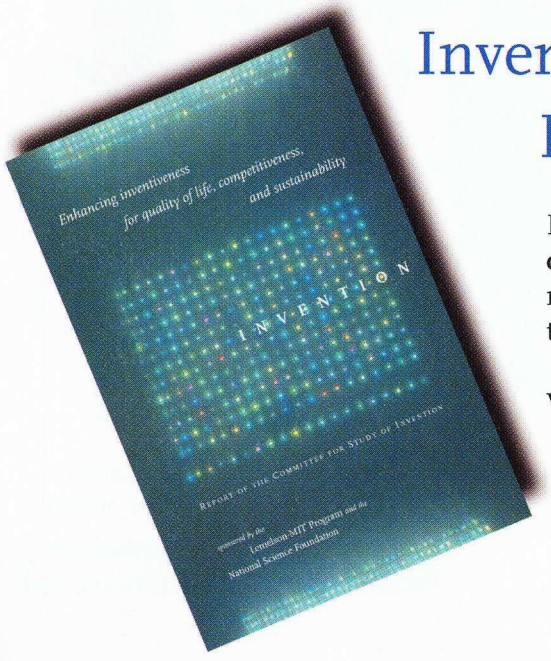

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HYBRID DEBATE REVS UP

PETER FAIRLEY'S ARTICLE WAS OVERenthusiastic about the economic value of hybrid cars ("Hybrids' Rising Sun," *TR* April 2004). He claims that switching to a hybrid car would save, on average, $5,000. This assumes, however, that the conventional car gets only 24 miles per gallon and that an owner would keep the same car for 15 years. But most Americans keep a car much less than that, and many gas-engine cars get more than 24 miles per gallon. The Toyota Corolla, which is about the same size as the Prius and has better performance, is priced $6,000 lower and consumes only about $400 per year more in fuel. You'd have to own a Prius for 15 years to break even. After a typical three- to four-year ownership, the Prius owner would still be deep in the hole compared to the Corolla owner.

Chris Bell
Washington, DC

I AGREE WITH ROBERT BUDERI'S ARTICLE "Finally, My Last Conventional Car" (*TR* April 2004). I bought my first hybrid last year. However, I would like to call attention to the line where he cites Toyota's and Honda's production records and plans for hundreds of thousands of hybrids on the road, and then lumps in General Motors' intent to be able to "build as many as one million hybrids by 2007." Toyota and Honda have a track record to back up their claims, but we should wait until GM does, too, before quoting their numbers in the same context. When I went to the Emerging Technologies Conference at MIT last September, Larry Burns, GM's vice president for R&D and planning, talked about GM's proposed fuel cell car to be released in 2010. But the technological hurdles that he mentioned all required improvements of at least a factor of 10. Burns also said that Toyota sold approximately 100,000 hybrid Priuses in 2003, a total that he dismissed as "insignificant." When he talks about GM's R&D on hybrids, he means the company's effort to give hybrid pickups and SUVs 20 percent better mileage—around 20 miles per gallon, a far cry from a mid-sized Toyota Prius that can get triple that mileage.

Andrew Heafitz
Cambridge, MA

PETER FAIRLEY IS ONE OF THE FEW journalists who seem to grasp how significant the hybrid is to the future of automobiles. Unfortunately, U.S.-based manufacturers have chosen to concentrate on fuel cells, which, when compared to advanced hybrids, look less and less affordable.

Robert J. Templin
Austin, TX

I WAS DISAPPOINTED THAT YOUR ARTICLE on hybrid cars didn't address the battery side of the issue. Do the nickel-metal-hydride batteries in the Prius last for the car's purported 15-year lifetime? If not, who pays how much to replace them? And when the car reaches retirement, what is the environmental impact of disposing of (or refurbishing) the batteries? Does Toyota have an infrastructure for this in place? I'd like to know how well the environmental-impact circle closes.

Matt Knapp
Englewood, CO

"Toyota and Honda have a track record to back up their claims. Wait until GM does, too, before quoting their numbers."

RUNNING WITH SERVERS

SIMSON GARFINKEL'S COLUMN "HOME Is Where the Server Is" (*TR* April 2004) is misleading and strains credibility. Getting a high-speed connection from your local cable or DSL provider is one thing; getting one that has a fixed IP address suitable for e-mail and Web servers is something else entirely. And while Garfinkel suggests that a server can be had for $400, his own system appears to cost over $1,500. It's true that a burglar is unlikely to steal a server, but there are other ways to lose data: it is a lot easier to run out of a burning house with a laptop with 60 gigabytes' worth of data and memories than a rack-mounted server.

Hayung Choi
Temecula, CA

Simson Garfinkel responds: When I wrote the article, Speakeasy was offering a static IP address for $39.95 with DSL. Even with a dynamic IP address, you can use dynamic DNS to get a fixed name, which is what really matters. As for the cost: I put together a Linux system using a $399 Dell computer with 256 megabytes of memory and 60 gigabytes of disk space. There are, of course, many ways to lose data; that's why I do off-site backups every night.

CORRECTION: Our May 2004 cover story, "Sparking the Fire of Invention," misquoted Nathan Myhrvold regarding technological competition with Microsoft. Myhrvold actually said, "I can't outdevelop Microsoft and Oracle in databases, but I may be able to outinvent them."

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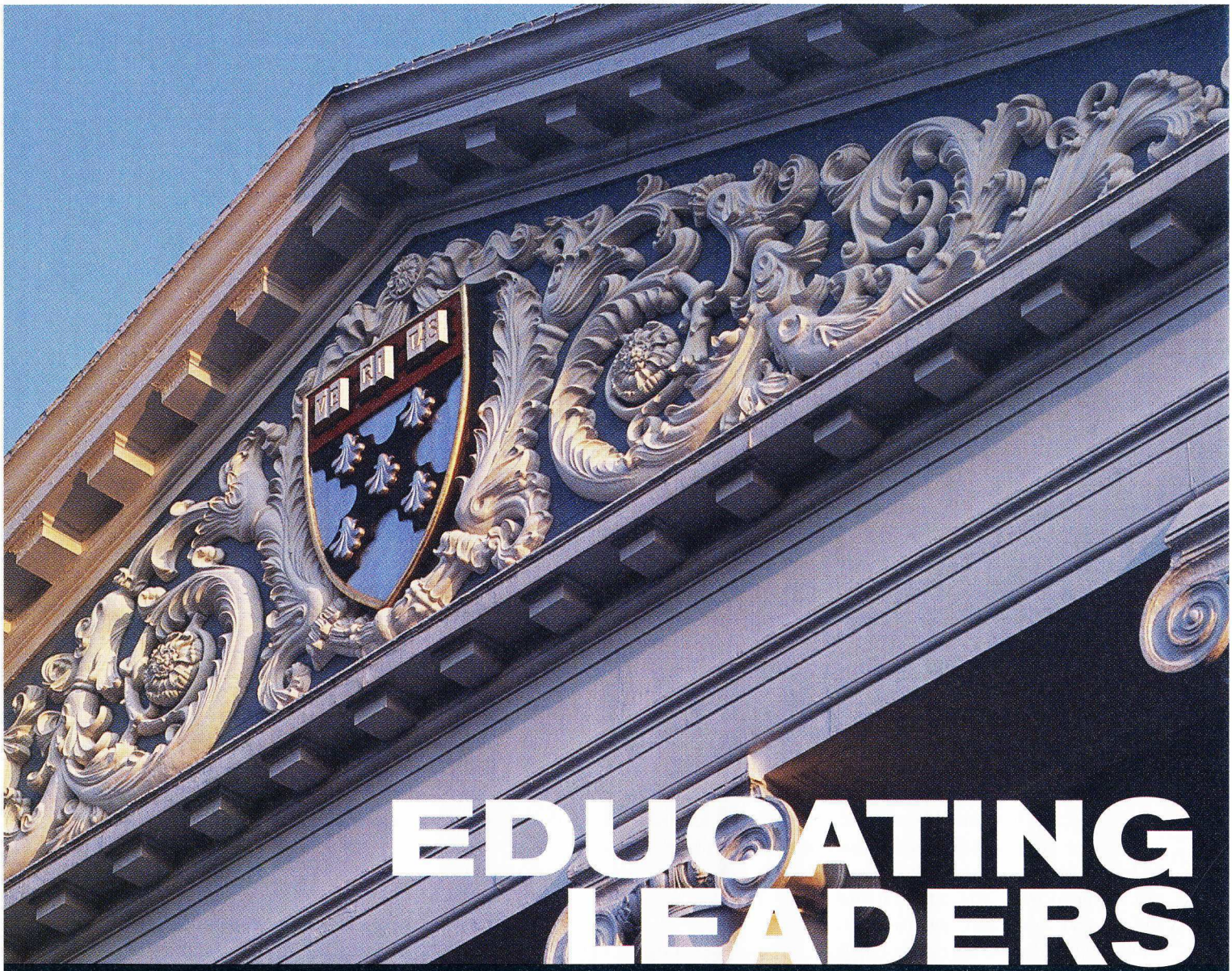

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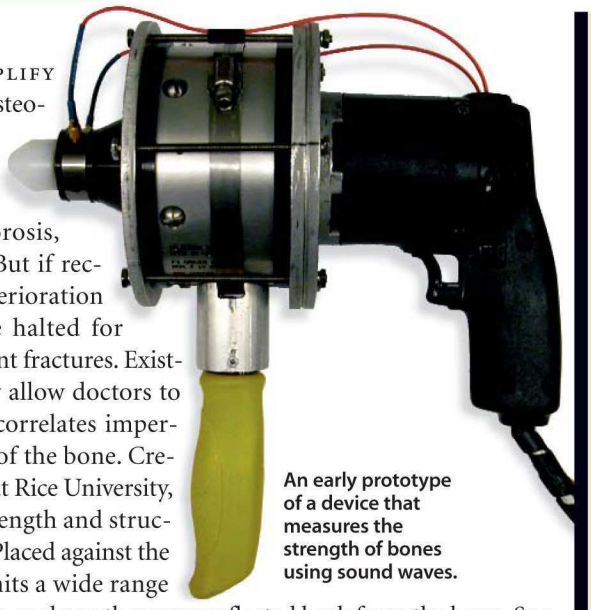
SOUND BONES

A NEW DEVICE COULD SIMPLIFY and improve the diagnosis of osteoporosis, allowing doctors to detect and treat this crippling disease earlier. About 10 million Americans have osteoporosis, which leads to bone fragility. But if recognized early enough, the deterioration caused by the disease can be halted for many patients, helping to prevent fractures. Existing diagnostic techniques only allow doctors to measure bone density, which correlates imperfectly with the actual strength of the bone. Created by a team of bioengineers at Rice University, the new test determines the strength and structural integrity of bone directly. Placed against the skin, the OsteoSonic device emits a wide range of acoustic frequencies and then analyzes the waves reflected back from the bone. Specific acoustic responses are characteristic of different properties of bone, indicating its strength or the presence of fractures. Changes in bone integrity "can be picked up earlier," says Michael Liebschner, who led the Rice team. The new test should also be far cheaper than existing scans, which cost hundreds of dollars and must be done in specialized labs. "A family physician could monitor a patient in his office, every other month," Liebschner adds. Liebschner has begun tests of the device with several hospitals and clinics in the Texas Medical Center. He and his team are forming a company to commercialize it; he hopes to have regulatory approval within three to five years.



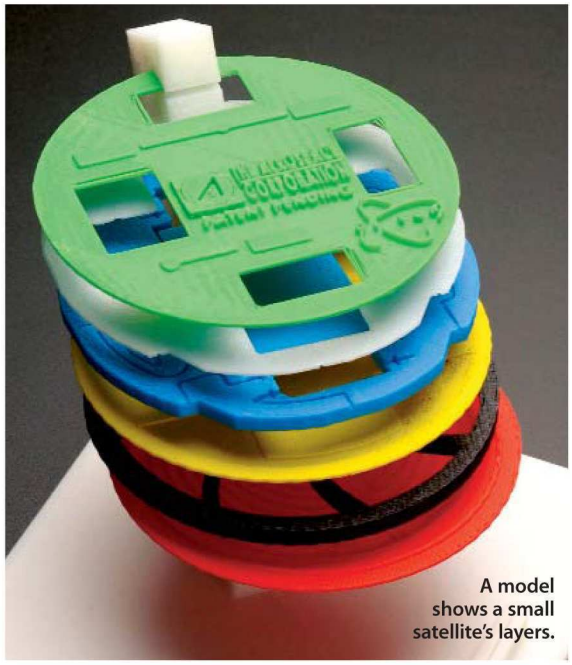
An early prototype of a device that measures the strength of bones using sound waves.

READ MY LIPS

Computers that observe facial expressions could personalize online communications, make video games more interactive, and read lips to help recognize speech. But facial expressions change so quickly and unpredictably that computers have trouble keeping up. At Tsinghua University in Beijing, China, computer scientist Guangyou Xu has developed software that takes video of a person's face and traces an accurate outline of the lips from frame to frame. Xu first trained a computer to draw the 2-D outline of a goldfish swimming back and forth in a bowl; from this, he developed an algorithm that represents the complex motion of lips using just a few mathematical parameters. That enables the computer to learn the lips' typical range of movement, so it can distinguish them from other features, like teeth, more accurately than current techniques. Xu is in discussions with companies to commercialize the software, which could be used to make video games and online chat rooms more vivid and, eventually, to analyze surveillance video.

SMALL SATELLITES

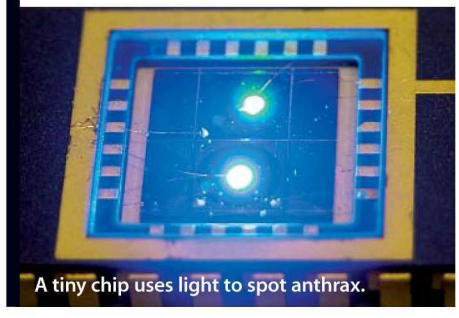
AT A CONSISTENT $12,000 to $22,000 per kilogram, it's not getting any cheaper to send satellites into space, so researchers are trying to figure out how to make them lighter. One extreme solution: hockey-puck-sized satellites. At defense research center Aerospace in El Segundo, CA, engineers are creating early prototypes in which propellant tanks, thruster nozzles, and other key components are laser-carved from a special type of glass. Other necessities such as metal valves, tiny microelectromechanical gyroscopes, guidance electronics, cameras, and other sensors are bonded to the structure. Led by aerospace scientists Siegfried Janson and Henry Halvajian, the team is testing the devices' maneuverability on a platform similar to an air-hockey table; if the tests go well, the small satellites could ride into space on the sides of other, larger satellites within four years. Once in space, they would be deployed as needed to send back pictures of their host satellites' condition. Eventually, Janson says, fleets of these satellites could replace some of today's hefty sensing and communications satellites.



A model shows a small satellite's layers.

SPOTTING ANTHRAX

DETECTING ANTHRAX AND OTHER bioweapons typically requires bulky equipment. Now engineers at the University of California, Berkeley, and Purdue University have devised a sensor chip only five millimeters square that could do the job. The chip uses standard fluorescence detection technology but shrinks it enough that it can fit in a handheld device. A dye attached to a molecule that reacts with anthrax would be added to a test sample in a plastic cassette clipped to the chip. Light from a tiny light-emitting diode would make any sample containing anthrax glow, and a detector would pick up the fluorescence. The team is now looking for a partner to develop the chip into a product.



A tiny chip uses light to spot anthrax.

COURTESY OF ZHONGSHENG LUO (SPOTTING ANTHRAX); COURTESY OF THE AEROSPACE CORPORATION (SMALL SATELLITE); COURTESY OF MICHAEL LIEBSCHNER (SOUND BONES)

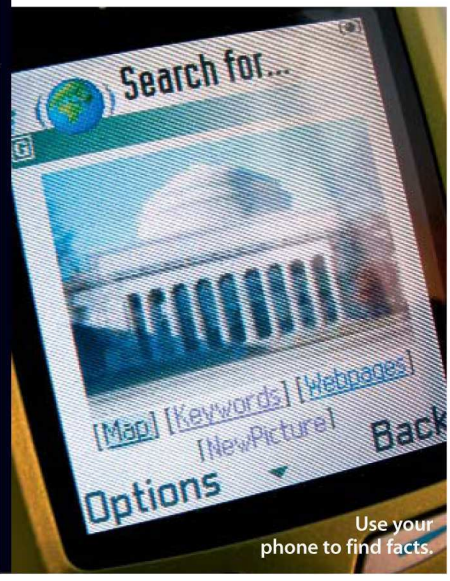
CUSTOM GLASSES

YOU PROBABLY THINK OF EYEGLASSES AS PERSONALIZED, but in fact current ophthalmic methods only correct for the most common vision problems—leaving the remaining 20 percent uncorrected and many glasses wearers seeing stars, halos, or other apparitions. A San Diego, CA-based startup, Ophthonix, is developing a system—which could be on the market by year's end—for making glasses that are truly tailored to a person's unique vision flaws. The process begins with a device that measures all of each eye's aberrations, such as irregularities in the shape or density of the lens or cornea. Conventional diagnosis, in contrast, relies on a patient's subjective choices from among a series of corrective lenses. The Ophthonix device shines light into the eye and measures changes in the wave properties of the light reflected back by the retina; from these changes, it can calculate the measurements of any existing irregularities. The system then uses those measurements to create a digital prescription that it forwards electronically to Ophthonix. At the company, the prescription guides a laser as it scans a lens made up of a layer of conventional material fused to a layer of a novel polymer developed by Ophthonix. The laser light changes the molecular structure of Ophthonix's polymer, altering its refractive properties from one point to the next. In tests on patients, even those with 20/20 vision could see more clearly with the new glasses.

A device finds vision flaws.

PICTURE THIS

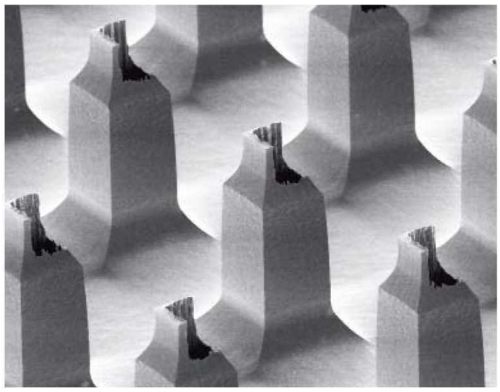
NOT SURE YOU'VE MADE IT TO THE right building on a crowded college campus? Think you might like to buy a car like one you see across the street but don't know what kind it is? Why not use your phone—not to make a call, but to take a picture and use it to search for the desired information? Technology developed at MIT's Computer Science and Artificial Intelligence Laboratory will, once it's loaded on your phone, send the image to a database that compares it to other pictures and then present you with a list of matches, together with details such as the address and name of the building or the make, model, and price of the car. Called iDeixis, it works together with a server that crawls the Web for pictures, identifies shapes, colors, and other major details, and stores them in a compact format in a dedicated database. The researchers hope the service will be available in your phone in a few years.



Use your phone to find facts.

PRIVATE EYE

At airports, border crossings, and hospitals, iris recognition systems are gaining wider use. But they tend to be fixed and clunky, requiring people to stand in specific spots so that wall-mounted cameras can scan their irises. At the Chinese Academy of Sciences' Institute for Automation in Beijing, China, electrical engineer Tieniu Tan's group has developed a portable system that could enable security guards to scan people in line; it could also provide cell phones and other mobile devices with built-in authentication systems. Tan's handheld scanner uses near-infrared light to illuminate the eye, while an embedded camera captures images of the iris. Using speech synthesis software, the handheld can even tell the subject to move closer or farther away as needed. Novel image-processing algorithms select the clearest iris image—one that's in focus and unblocked by eyelashes—and analyze its tiny freckly patterns. Tests show the system is more than 99 percent accurate—as good as today's best stationary models. Some of the software runs on a desktop computer, but Tan is developing a completely portable system through a Beijing-based startup, Pattek. Its first application: authenticating users who log onto laptops, handhelds, and ATM machines.

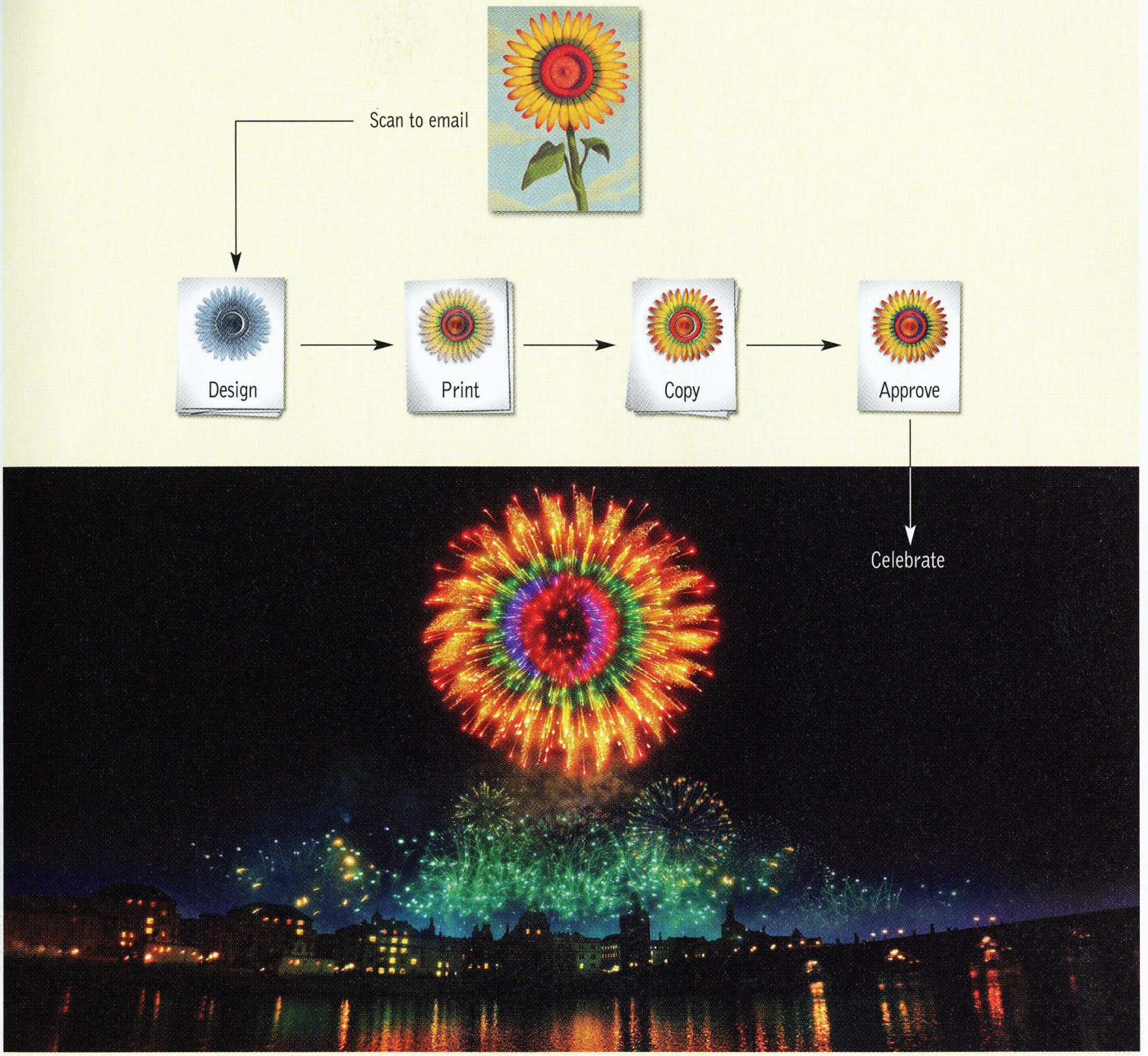


Minute needles make diabetic testing painless.

SKIN DEEP

DEVICES THAT CONTINUOUSLY MONITOR BLOOD SUGAR LEVELS ARE REPLACING painful finger-stick tests for many of the United States' 18.2 million diabetics, but they typically must be implanted under the skin by medical technicians. A prototype developed by engineers at the University of California, Berkeley, could provide a way around this inconvenience. Stefan Zimmermann, Boris Stoeber, and Dorian Liepmann at the Berkeley Sensor and Actuator Center employed the same lithographic techniques used to create microchips to build an array of silicon microneedles, each about 200 micrometers long. The array is simply placed on top of the skin, where the needles puncture deeply enough to reach the fluid between cells, but not deep enough to hit nerves or blood vessels. A sensing device above the needles analyzes the fluid to determine blood sugar levels. Zimmermann says Berkeley is in negotiations to license the technology to medical-device makers.

COURTESY OF STEFAN ZIMMERMANN (SKIN DEEP); COURTESY OF KONRAD TOLLMAR (PICTURE THIS); DESIGN DESIGN (CUSTOM GLASSES)



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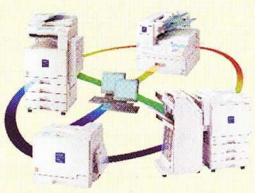

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YOUR SUCCESS IS OUR BUSINESS

Wicked Innovation

I LOVE YOU. ■ I LOVE YOU WITH A PASSION THAT burns like a white-hot nova. As a digital testament to my love, please put this magazine down and immediately go to iloveyouutterly.com to download a very special "I love you" screen saver. You'll love it almost as much as I love you. ■ Are you back? Actually, I don't love you. I never did. In fact, I'd think you were a few bits short of a byte if you ever clicked to such a site or opened an "I love you" e-mail attachment from someone you've never met. Nevertheless, millions of PC owners have had their machines brought to their metaphorical knees by viruses and worms (virms?) promising love from strangers, "wicked screen savers," or compromising photos of Anna Kournikova. Lord, what fools we mortals be.

But let's turn these bugs into a feature. Cold, dispassionate analysis affirms that such "virmen" are among computerdom's most successful innovations ever. They've utterly transformed the network experience. They're global; they're local; they're persistent; they're pervasive. They cleverly exploit both human and technical weaknesses. They matter.

The proliferation and permutation of viruses and worms offers a superb case study in wicked innovation and innovative wickedness. Why do such innovations succeed? What can and should we learn from their continuing success? Just as society better understands health by better understanding disease, markets better appreciate healthy innovation by grasping the dynamics of pathological innovation.

Deception is at the dark heart of wicked innovation. Alluringly misrepresented e-mail attachments and "phishing" expeditions—the fraudulent use of corporate names and logos to gather people's credit card numbers—are only the most obvious examples. The use of anabolic steroids, human growth hormone, and other illicit performance enhancers in baseball, football, and Olympic sports represents another genre of effectively deceptive innovation. In a field where the price of being found out is high, these "natural" substances give users a competitive edge with a low risk of detection.

Honesty compels us to admit that dishonesty is often a superb innovation strategy.

Precisely because cheating is the essence of wicked innovation, we need to rethink the role of competition in its pathology. Two kinds of innovators stand out. The first are those who "compete with" each other; that is, they respect certain rules in their efforts to succeed in the marketplace. The second are "compete against" innovators whose goal is to spread their own inventions and eliminate their competition, free choice in the marketplace be damned. Compete-with innovation is about value creation; compete-against innovation is about value negation.

Microsoft vs. open source is a classic compete-with contest; both sides, for the most part, play fair. World War II's "Battle of the Beams" between German and British engineers trying to coordinate—and thwart—electronic navigation aids for nighttime bombing raids is a perfect example of a compete-against innovation marketplace. The compete-against dynamic is an escalating innovation arms race where the economic goal is less to create new value for customers than to defeat or hoodwink the enemy. The conflict is defined by "measure vs. counter-measure vs. counter-countermeasure." The result? Deceit, deception, and misrepresentation are the mission-critical media for compete-against innovation.

Viruses, identity theft, performance-enhancing drugs, phishing, and other compete-against innovations succeed because they so effectively exploit both human virtues and human venality. They alternately appeal to the seven deadly sins—vanity, sloth, envy, gluttony, etc.—and to our compassion and curiosity. "Social engineering" matters as much as technical engineering.

Equally important, wicked innovators prey upon the fact that in most arenas of technology, security and authenticity are afterthoughts. The Internet, for example, was never designed with security in mind; the most important protections have all been retrofits. Neither the Olympics nor Major League Baseball evolved with the expectation that so many world-class athletes would choose to cheat chemically. Pathological innovation has moved cheating from the margins to the mainstream.

Should compete-with innovators fight fire with fire and use deception of their own to combat wicked innovators? Should they give their customers and clients better tools to battle pathological innovation? Or should we simply throw up our hands, declare wicked innovation a "public policy" issue, and count on the regulators, courts, and legislators to rescue us?

The correct answer, of course, is "all of the above." Honesty compels us to admit that dishonesty is often a superb innovation strategy. Compete-with innovators have little choice but to grow a bit trickier and more deceptive in their own security investments, creating tools such as the online "honey pots" that use dummy credit card data to lure in and trace hackers. Wicked compete-against innovators, ironically and inevitably, will increasingly drive innovation in compete-with markets. The single most important lesson pathological innovation teaches is that the economics of cheating play as great a role in defining value as the economics of adoption. You've got to love that. TR

A researcher and consultant on innovation economics, Michael Schrage is the author of *Serious Play* (Harvard Business School Press, 2000).

Boosting Biometrics

Multiple identity measurements are the key to better security. **BY ERIKA JONIETZ**

The demand for greater security at borders, government buildings, and companies has meant boom times for biometrics—technologies that measure biological traits to identify individuals. Systems that digitally fingerprint people, read the patterns of their irises, measure the unique dimensions of their faces, or verify their voices are expected to become a $1 billion business in 2004, quadruple what it was just five years ago.

But there's a problem: no single measurement works for everyone. As many as 3 percent of people lack readable fingerprints, and perhaps 7 percent have eye pigmentation that interferes with iris scans. Face recognition software can be thwarted by veils or thrown off by changes in hairstyle or lighting. And biometrics can be tricked: a fingerprint left on a sensor can potentially be lifted and used by someone else; many face recognition systems can be fooled by photographs or video clips. "No biometric has proven to be the ultimate," says Gary Strong, the manager of behavioral and biometrics programs in the U.S. Department of Homeland Security's science and technology office.

Now, corporate and academic labs worldwide are tackling these weaknesses by merging multiple biometrics into systems that are flexible, accurate, and virtually spoof-proof. These new, so-called multimodal biometrics generally take a probability score from each biometric measurement and combine them to provide a single thumbs-up or thumbs-down. Given the pressing demand for better security, revenue from multimodal biometrics is expected to soar from $11

JENNY LYNN

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Remote-classroom technology reaches new heights in China.

million in 2003 to $220 million by 2008, says Trevor Prout, marketing director of the International Biometric Group, a biometrics consultancy in New York, NY.

Software made by HumanScan of Erlangen, Germany, uses face recognition, voiceprints, and lip motion to identify people—the first commercial multimodal biometric identification product. It starts by preparing a data template for each person who might later need to be screened. A standard video camera equipped with a microphone records one second of video and voice, and the software uses that data to create a unique template. Later, the template can be used to verify identity based on all three signatures. Managing director Robert Frischholz says HumanScan's combination yields far higher accuracies than individual biometrics. "If you add them all together, you get better results—much better results," he says.

HumanScan's technology is already being used to protect certain restricted military computer networks and to safeguard casino customers' money from being claimed by imposters. But this year the company, in collaboration with IBCOL, a technology commercialization company based in Munich, Germany, is moving to pilot installations that will verify the identities of travelers entering and exiting the United States and Germany. The company will not discuss which biometrics are being used. But there's already a growing lode of biometric data on travelers. For example, the United States requires that all visitors (except those from Mexico and Canada) submit to digital fingerprinting and photography.

Meanwhile, biometrics leader Identix, of Minnetonka, MN, is enhancing its two existing systems—face recognition software and fingerprint scanners—by adding a third biometric to the mix: skin texture. Identix's new identifier is called a skinprint, and it's captured by algorithms that extract texture patterns from digital camera images. "Dermal textures are unique, and they are random," says Joseph Atick, president and CEO of Identix. Atick says adding texture recognition to Identix's existing face recognition systems—an advance the company is bringing to market this year—boosts accuracy from 70 percent to more than 90 percent. Atick says that with the new technology, face recognition systems can distinguish between identical twins, making them as accurate as fingerprinting—long considered the gold standard of biometrics.

New face recognition software also checks skin texture characteristics.

COURTESY OF IDENTIX

The texture technology can take advantage of an enormous base of existing face recognition systems, a base that only promises to get larger. For instance, the United Nations' International Civil Aviation Organization has recommended that passports and other travel documents include chips that carry face data for identity verification, with either fingerprint or iris data permitted as secondary biometrics. Each country would collect this data during the passport or visa application process; biometric systems at airports and other entry points would verify holders' identities by scanning faces, fingers, or irises and comparing the data against the template on the microchip.

Identix is also experiencing new demand for its software, first released two years ago, that can combine any two biometrics. The technology, known as fusion software, essentially merges confidence scores from the two tests to verify a person's identity. In one of the more high-stakes examples, Israeli authorities are using the software to merge face recognition with a less frequently used biometric—hand geometry—to monitor the entrance and exit of 50,000 workers to and from the Gaza Strip.

Expanding on this combinational approach is a goal of Homeland Security research efforts. Agency-sponsored research has already created a laboratory prototype that joins three, four, or even more biometrics. The brainchild of Anil Jain, an electrical engineer researching biometrics at Michigan State University, the system can mix and match any combination of face recognition, fingerprinting, iris scans, hand geometry, and voiceprinting. What's more, Jain says, the system can give greater weights to specific biometrics depending on the reliability of different modes for a given individual.

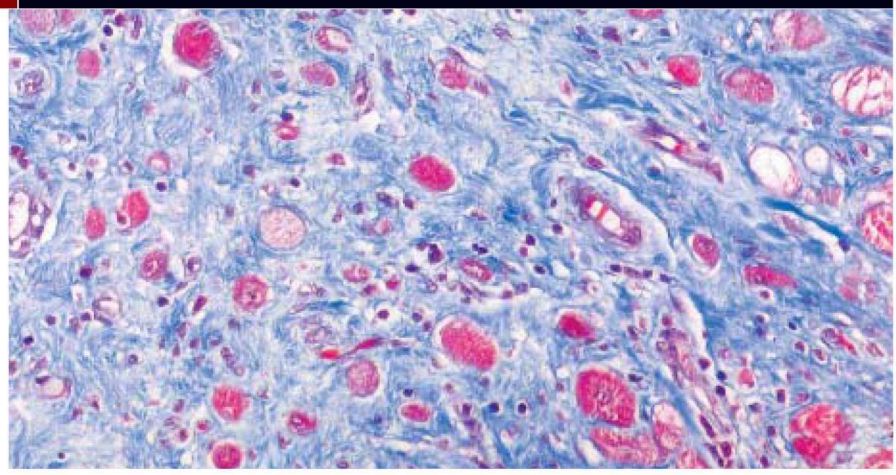
Some issues must be addressed before multimodal biometrics dominate the industry. Standards must be set, governments need to clarify which combinations will be accepted, and researchers need to determine how best to weight individual scores. But fusing biometrics is critical to truly reliable identification systems. "There is no such thing as one biometric wins all," Atick says.

BUILDING MULTIMODAL BIOMETRICS

GROUP	STRATEGY
HumanScan (Erlangen, Germany)	Analyzes face, voice, and lip movements to secure physical and network access
Identix (Minnetonka, MN)	Fuses data on skin texture with fingerprint or facial data
Vijayakumar Bhagavatula, Carnegie Mellon University (Pittsburgh, PA)	Integrates data from face, fingerprint, and iris biometrics
Mike Fairhurst, University of Kent (Kent, England) and Neusciences (Southampton, England)	Software agents to manage multiple biometrics, including voice, face, and fingerprint
Anil Jain, Michigan State University (East Lansing, MI)	Fuses data from different biometrics, including face, fingerprint, iris, hand geometry, and voice, and from different companies' systems

MEDICINE

Jogging Hearts Back to Health



Scar tissue (blue) in heart muscle is interspersed with transplanted leg-muscle cells (red).

EACH YEAR MILLIONS OF PEOPLE around the world survive heart attacks but then must live with scarred, weakened hearts that frequently enlarge to compensate for a diminished ability to pump blood. Ultimately, this condition can lead to heart failure and death. Researchers are finding some early signs that replacement cells from an unlikely source—leg muscle—could bulk up diseased hearts, helping to prolong life in heart attack victims.

Genzyme of Cambridge, MA, is now conducting tests of the treatment strategy in France and several other European countries with 300 heart attack patients. Researchers take muscle cells from a patient, cultivate a select group of those cells in petri dishes for two to three weeks, and then inject them directly into the heart's scar tissue. Preliminary research suggests these replacement cells strengthen the damaged wall of the heart, preventing bulging, says Ralph Kelly, vice president of clinical research for Genzyme.

GenVec of Gaithersburg, MD, and Bioheart of Weston, FL, have begun human tests of a similar technology in the United States. If the trials go well, in five to ten years, leg-muscle-cell injection could become an approved therapy, says John Fakunding, program director for heart research at the National Heart, Lung, and Blood Institute in Bethesda, MD. The treatment could potentially prolong life, Fakunding says. "The transplantation [of muscle cells] into the heart does appear to have a functional benefit," he says, "in that it may make the heart work better."

Most experts, however, suggest that the use of leg muscle is a short-term patch. For one thing, leg muscle cells don't beat, as cardiac cells do. And some researchers suspect that implantation can lead to arrhythmias, or irregular heart beating, in some patients. But leg muscle cells may well play a role "until better reparative methods, using other cells and transplantation methods, are developed," Fakunding says. Despite the caveats, that's hopeful news for people at risk for heart failure. **Corie Lok**

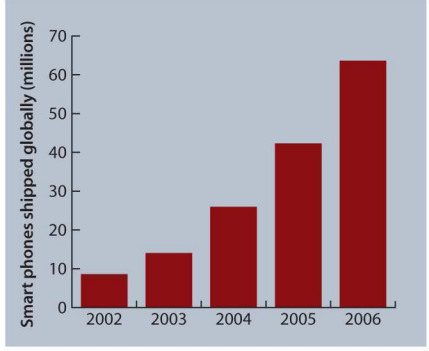
SECURITY

A Vaccine for Your Phone

Your home and office computers are probably protected by antivirus programs and firewalls. But what about your new cell phone? The latest "smart phones" let you read e-mail, open attachments, and download games and other programs. Just imagine if a virus slipped through that made toll calls to 1-900 numbers in the middle of the night. With phone spam already here *(see "Spam to Go," TR April 2004)*, industry experts suspect phone viruses are bound to come calling soon.

Anticipating the arrival of phone viruses, security software companies are starting to develop dedicated antivirus products. F-Secure of Helsinki, Finland, says that over the past year or so it installed virus detection systems in the networks of nine cell-phone service providers. This year, the company says, it will start selling antivirus protection software for phones themselves. "We don't want to wait for [an attack] to happen," says Mikko Hypponen, director of antivirus research at F-Secure. In most respects, the company's antivirus program works the same way as the one on your computer, examining incoming e-mails and files for known viruslike code patterns and behavior. But it's customized to work with the far smaller memory and lower processing power of a typical phone.

SMART-PHONE BOOM



F-Secure is not alone. Symantec of Cupertino, CA—the largest antivirus software vendor for PCs—earlier this year began working with the world's leading phone maker, Nokia of Espoo, Finland, to install virus protection. Symantec plans to offer security software for a new Nokia phone model expected to reach market later this year. And Microsoft, one of three major makers of operating systems for smart phones, says it is also increasing security.

Phone viruses are still a theoretical concern, but "it's bound to happen this year or in the beginning of next," predicts Sally Hudson, research manager at IDC, an information technology consultancy in Framingham, MA. If phone viruses do attack, with any luck the new programs will hang up on them. Patric Hadenius

SOURCE: STRATEGY ANALYTICS FORECAST (PHONE BOOM); COURTESY OF THE *JOURNAL OF THE AMERICAN COLLEGE OF CARDIOLOGY* (HEARTS)

PlaceLab's cabinets include hidden cameras, movement detectors, microphones, and other sensors.

SENSORS

The Digital Apartment

Gleaming hardwood floors. Recessed lighting. Computers gathering data on every flick of a switch, flush of a toilet, or opening of a cabinet. It's all in an apartment nearing completion in Cambridge, MA, that doubles as PlaceLab, whose creators say it's the world's most elaborate residential laboratory for studying how people interact with their homes. Packed with discreetly installed sensors, microphones, and cameras, it's a lab for prototypes and testing health-care systems, smart appliances, the latest environmental controls, and whatever else companies and academics want to study.

The 90-square-meter space is a joint project of MIT and Tiax of Cambridge, MA. While academic labs and companies like Intel, Philips, and Microsoft have been showing off smart-home demos for years, the leaders of the Cambridge project say this is the first one that's both heavily sensor-riddled and also an actual apartment where people will live, albeit as voluntary test subjects for periods of about two weeks. "Nobody has built a scientific instrument like this, to measure the complex interaction of people and technology," says Kent Larson, an architect and director of the MIT research consortium involved in the project. "You can only go so far in an academic or corporate research lab."

First up: a study of what people actually do about diet and exercise, compared to what they say they do. Key objectives down the road include the testing and development of technologies that remind people to make healthier decisions. Such reminders could be anything from audio messages to changes in lighting hue or intensity.

Tiax even hopes to evaluate the sensing technologies themselves, says company president Kenan Sahin. Everyone recognizes that an aging population will need better monitoring *(see "Monitoring Mom," TR July/August 2003)*. What's not so clear is which technologies—wearable radio-frequency identification bracelets, cameras, or sensors on dishes, medicine bottles, and cabinet doors—are most practical. Tiax hopes to provide manufacturers hard data on which systems function well and might be easily packaged and sold to builders. "We want to know how to embed them into the infrastructure of the home affordably," Sahin says. "The home is a system; people interact with and are part of that system." This much is clear already: there will be plenty of ways to watch how that interaction unfolds. **David Talbot**

A partial PlaceLab floor plan shows sensor coverage.

ELECTRONICS

Networking Your Gadgets

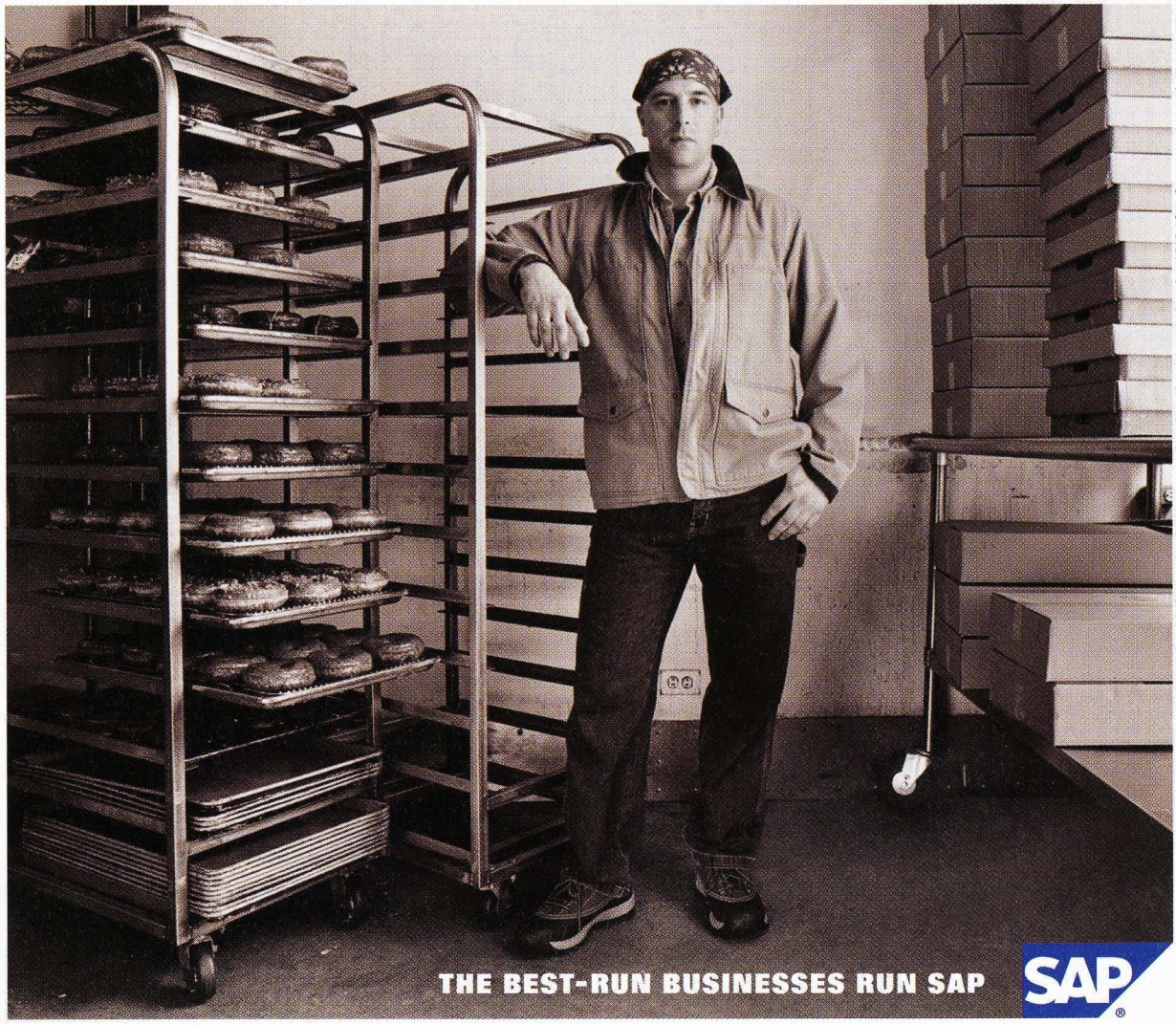
It sounds simple enough. Display your digital photos on the TV, or play songs stored on your PC through your stereo. Don't bother trying, though, because the typical computers, DVD and MP3 players, cameras, and televisions that pervade millions of homes can't all communicate with one another. After years of industry promises, however, that could be about to change. The first products that will allow for easy networking of a wide range of gadgets could arrive on store shelves as early as this holiday season.

The main roadblock was cleared this spring, when consumer electronics, chip, and computer makers agreed to a new common set of standards. Now, manufacturers are using those standards to build next-generation products that exchange songs, video, and photos with each other, via either wired or wireless local networks. While certain high-end products can already do this, "we're trying to make it more plug-and-play for mainstream consumers," says Bob Gregory, director of initiatives planning at Intel and a board member of an industry consortium of more than 100 companies—including Microsoft, Sony, and Hewlett-Packard—that established the new standards. At first, gadgets will exchange data via special adaptors, though manufacturers will next make devices with the networking capability built in.

"It's a great first step" toward expanding the home network beyond just PCs, says Mike Wolf, an analyst with In-Stat/MDR, a market research firm in Scottsdale, AZ. "Eliminating the lack of interoperability is a great hurdle they've overcome," he says. Within the next year or two, instead of being stuck in front of a computer looking at digital photos, you could find yourself on the living room couch with the photos on a big-screen TV. Corie Lok

IMAGES COURTESY OF THE MIT HOUSE_N CONSORTIUM AND TIAX

COMPANIES THAT THOUGHT THEY COULDN'T AFFORD SAP RUN SAP.



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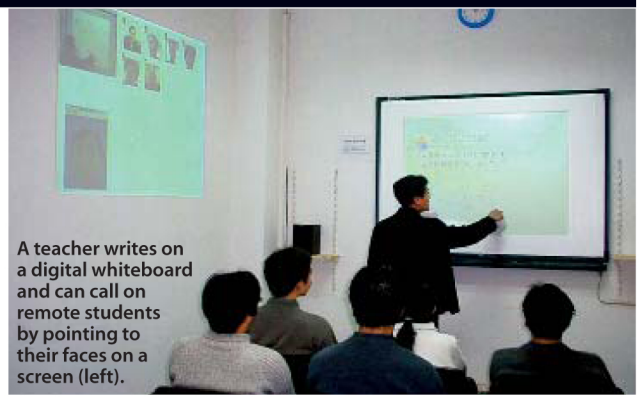
MULTIMEDIA

China's Clever Classroom



A teacher writes on a digital whiteboard and can call on remote students by pointing to their faces on a screen (left).

At Tsinghua University in Beijing, China, all eyes are on Professor Yuanchun Shi. But it's not the computer scientist's lecture that's so riveting—it's how she's giving it. One wall of her "smart classroom" displays photos of students at other universities across China who have logged in. Shi poses a question and calls on a remote student by shining a laser pointer on his photo. "Go ahead," the teacher says. The student's picture switches to live video and audio as he answers. Shi writes on a digital whiteboard that transmits her handwriting to the students' computers, complementing audio and visual feeds from cameras and microphones.

Shi's smart classroom is one of the most advanced in the world. Wide-scale testing is under way, and commercialization is planned, initially within China.

Until now, most smart classrooms for distance learning have required teachers to use desktop computers to run their classes. But this version allows Shi to lecture and interact with remote students more naturally, using speech, gestures, and handwriting. "They are certainly doing some interesting things that other people have done before in isolation but not together in an all-in-one package," says Jason Brotherton, an expert in computer-enhanced education at University College London who is developing his own distance-learning classroom.

Shi's classroom relies on some technological wizardry. In the back of the room, behind a curtain, is a rack of seven computers. Computer-vision algorithms coordinate eight video cameras that track the teacher's movements, switching views as she points to a page in a textbook or writes on the whiteboard. The computers recognize the positions of her arms and zoom in on particular gestures. The system also tracks the trajectory of the laser pointer and responds to simple spoken commands. Remote students' desktop computers are equipped with video cameras, microphones, and communication software to allow them to send and receive multimedia data.

Last summer, 180 students took part in a computer science course at Tsinghua, one of the country's top technical schools, from their dorm rooms. And since last winter, hundreds of students in a half-dozen cities in China have joined the class. Now, working with Beijing MoVision Technologies, a multimedia telecom firm, Shi plans to commercialize the system's software within a year. Her first customer: Tsinghua's Continuing Education School, which could grant remote access to as many as 20,000 students. **Gregory T. Huang**

LEADERS IN COMPUTER-ENHANCED EDUCATION

RESEARCHER	PROJECT
Gregory Abowd, Georgia Institute of Technology (Atlanta, GA)	Multimedia technologies for recording and enhancing classroom lectures
Ron Baecker, University of Toronto (Toronto, Ontario)	Web-based interactive audio and videoconferencing for universities
Jason Brotherton, University College London (London, England)	Experimental classroom for enhanced distance learning
Yuanchun Shi, Tsinghua University (Beijing, China)	Smart classroom for interactive distance learning

TELEMATICS

Getting Direction from Your Phone

Forget about asking for help at gas stations. Your cell phone is rapidly becoming a one-stop source of directions. Over the past year, several startups have launched services that send directions to your phone's screen and provide a speech interface that reads them as you drive.

In most cases, these services require location information from a separate Global Positioning System receiver plugged into the phone. A lost driver dials up the service, which interprets a spoken description of his or her destination, calculates a route based on the GPS coordinates, and transmits directions back to the phone. New versions eliminate the external GPS receiver: gpware of Menlo Park, CA, plans to introduce a device this summer that includes a GPS receiver and cell-phone technology in a personal-digital-assistant-sized case that can be mounted on a car's dashboard.

These direction finders are a big step up from the navigation hardware sold with some cars, which uses maps stored on CDs or DVDs that typically need to be changed when a driver visits a new area. And only about 10 percent of new vehicles sold in 2003 had such "onboard navigation" built in, says Phil Magney, principal analyst with the Telematics Research Group in Minnetonka, MN. That leaves plenty of room for "offboard navigation"—cell-phone systems.

The newer technology has advantages, says Magney. "It translates into lower cost compared to what you might buy in a car. It's go-anywhere, meaning you can take it from your car to a rental car," and you're likely getting the most current data, he says. He predicts offboard navigation services will help boost the North American market for wireless in-car systems from $4.9 billion to $18 billion by 2010. **Wade Roush**

COURTESY OF YUANCHUN SHI AND TSINGHUA UNIVERSITY

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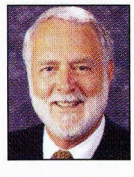

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The Cell Hijackers

BACK IN THE 1940S, JOHN VON NEUMANN—A GIANT in the development of modern computers—investigated the theoretical possibilities of self-reproduction. He essentially asserted that a self-reproducible machine would require a "tape" or other description of itself. During reproduction, this tape would serve as the set of instructions for building a copy of the machine and would itself be copied to create the seed necessary for the next generation.

DNA, of course, turned out to have precisely these properties. What a beautiful story! One of the very first computer scientists, a mathematician and engineer, made a prediction of the fundamental mechanism of life that biologists subsequently discovered. The truth, of course, turns out to be a little more complicated. But in a forthcoming denouement, engineering is poised for a triumphant comeback in molecular biology.

The last fifty years of molecular biology have largely been devoted to understanding the incredibly complex mechanisms that govern life. Scientists have developed wonderful analytic tools to study what goes on in cells. Now, we are on the brink of an engineering revolution that will transform our ability to manipulate the biological world. The results could be everything from cell-based computers to custom-made microbes that neutralize toxic waste or manufacture chemicals. It's a leap as large as that from ancient alchemy to today's materials science.

This engineering revolution is coming to be known as synthetic biology, and what follows are two examples of some early progress in the field.

The first: a bacterium that computes. At MIT, Tom Knight, Drew Endy, and their students have been modifying protein production processes to turn *E. coli* cells into primitive digital computers. The researchers used one protein to turn on and off a gene that codes for another protein. The resulting high or low concentration of the second protein corresponded to a *1* or *0*. Of course, from this fundamental "not" gate, as computer scientists call it, all digital logic follows. Knight and Endy's goal isn't to use cells to build future PCs. Rather, it is to gain digital control over the production of certain proteins and thus to hijack the cells for their own purposes. The cells they use provide a self-sustaining, living chassis that can readily make copies of itself and the altered DNA. The researchers have initiated a multiuniversity project to produce a catalogue of parts that will enable engineers to rapidly produce new circuits and perform computations in cells.

We're on the brink of an engineering revolution in biology. Eventually, we may put cells to work as computers or factories.

Progress continues: last year, teams of MIT students attempted to create oscillators that turned a jellyfish gene for fluorescence on and off so that *E. coli* cells containing the gene visibly blinked under a microscope. And this year a different group of MIT students attempted to genetically program a sheet of identical cells to recognize their relative spatial arrangement so that groups of them could fluoresce, making patterns on the sheet.

Obviously, these and similar feats at other universities are mere lab demonstrations of this promising technology. But the next few years may see applications that include the creation of cells that are genetically altered to deliver drugs within a person's body: one still theoretical idea is to program a cell to sense blood sugar levels and produce just the right levels of insulin in response. Another application could be in chemical manufacturing—biologically based factories in which worker cells follow molecular messages detailing which chemicals to produce.

The second example of synthetic biology is a rather different engineering project at the Institute for Genomic Research in Rockville, MD, founded by Craig Venter (yes, the same Craig Venter who sequenced the human genome). Venter and colleagues are working with a very simple bacterium, *Mycoplasma genitalium*, which has only 517 genes. They knocked out genes from the bacterium in an effort to construct a laboratory organism that has the minimal number of genes needed to sustain life and thereby identify a set of functional requirements for a living system. Their goal is to mix and match genes with those functions from different organisms to create a unique living system. Now that's engineering!

If they succeed, the benefits will be myriad. Right now, Knight, Endy, Venter, and others are limited to experimenting with existing cell lines. This is similar to saying every wheeled vehicle has to use a chassis from some finite set of automobiles, like Detroit's offerings from 1970. But when it becomes possible to engineer whole new cells from basic components, future engineers will be able to create custom organisms, their own DeLoreans, to perform specific biochemical tasks, such as producing hydrogen.

Where does this lead? Whereas now we grow a tree, cut it down, and build a table, in fifty years we might simply grow a table. As more engineers work on biological systems, our industrial infrastructure will be transformed. Fifty years ago it was based on coal and steel. Now it is based on silicon and information. Fifty years from now it will be based on living systems. Sort of like a new agricultural age, only of a radically different kind.

Rodney Brooks is director of MIT's Computer Science and Artificial Intelligence Laboratory.

Face to face: Jiang Li and Keman Yu demo handheld videophones.

THE WORLD'S HOTTEST COMPUTER LAB

WITH ITS STARTUP MENTALITY AND VAST AND DEDICATED TALENT POOL, MICROSOFT'S BEIJING RESEARCH LAB IS PUSHING THE FRONTIER OF COMPUTER SCIENCE—AND THE COMPANY'S GLOBAL MARKET.

BY GREGORY T. HUANG ▪ PHOTOGRAPHS BY KEVIN LEE

HALF A WORLD AWAY

from the calm beauty of Seattle and Puget Sound, there's a lab where software dreams come true. At Microsoft Research Asia, the drive to succeed is as intense as the traffic that roars by the front door in unbridled, chaotic fury. If Microsoft's other facilities around the globe seem idyllic, this one, in Beijing, China, is pure street. Nearby high-rises compete with smokestacks for skyline supremacy. Run-down buildings sit next to bustling consumer electronics markets and the Beijing Satellite Manufacturing Factory, where China conducts its spaceflight research. Microsoft's mantra: work hard to get in the door; work harder to survive; then work even harder because the real work—that of an information technology world leader—is just beginning.

If you find it hard to root for Microsoft, you've never met Harry Shum. The Beijing lab's managing director is hearty, engaging, and surprisingly young—in his 30s. "This is a new kind of manufacturing in China," he says, waiting outside his office with a smile. "Not just shoes, socks, baby strollers. Now, we manufacture MIT students, papers, and software." Shum's longtime colleague Hongjiang Zhang is walking by but stops to concur: "It's another level of 'Made in China,'" he says. Zhang, who's a little older than Shum and more reserved, heads the lab's Advanced Technology Center, a division launched late last year to accelerate new technologies into Microsoft's product pipeline.

Together, Shum and Zhang lead an organization that looks like a typical corporate lab but *feels* like a startup. For all its cubicles and computers, the lab brims with enthusiasm; its energy comes from, of all things, students. Come in at any hour and you'll find scores of them—the lab supports about 200 interns at any time, most from local universities—tooling away on projects jointly supervised by Microsoft managers. Add the buzz of Mandarin conversations, the window views of Beijing's sprawl, and the ever present hint of cigarette smoke, and you are constantly reminded: you're not in corporate USA anymore.

Although they run the lab, Shum and Zhang are at heart still researchers. Roaming up and down vast aisles of workstations, they show off their latest demos like proud parents. Shum stops at the desk of a young woman he calls "the number-one student" in computer science at Tsinghua University, one of China's top engineering schools. On her screen are still photos of a waterfall, rain on a lake, and blades of grass. With a click of the mouse, the scenes come alive. Water tumbles and splashes over the falls, raindrops plunk on the surface, and grass undulates in the breeze. The computer is generating the animation on the spot: software has scoured videos for statistical clues about how water and grass move and applied the lessons to the static images.

It's all part of the lab's ambition to lead the world in making computers interactive, entertaining, and ultimately more useful. Other demos include compression algorithms that store rich pictures using relatively few digital bits; computer vision software that tracks and recognizes human faces; a natural-sounding speech synthesizer; and user interfaces that capture handwriting digitally *(see "Microsoft's Magic Pen," TR May 2004)*. "They're doing really first-class research," says Victor Zue, codirector of MIT's Computer Science and Artificial Intelligence Laboratory and a member of the Beijing lab's technical advisory board. And Raj Reddy, a renowned expert in human-computer interaction at Carnegie Mellon University, calls the lab's leadership and talent pool "outstanding."

Indeed, with 150 full-time researchers and more than $80 million from its parent company since opening in 1998, Microsoft Research Asia has become a powerhouse of infotech R&D. Far faster than even Microsoft's top brass expected, the Beijing research outpost is influencing the company's global business. More than 70 technologies it developed are already used in Microsoft products, including software for Windows operating systems and graphics packages for Xbox video games. More of the lab's latest software is slated for the next version of Windows (code-named Longhorn), due out in 2006.

The Beijing lab is a key part of Microsoft's effort to ensure its global future through research. "It's interesting how much of the research directed at the Asian marketplace turns out to be generally applicable," says Rick Rashid, senior vice president of Microsoft Research, which besides its main facility in Redmond, WA, also runs labs in San Francisco, Mountain View, CA, and Cambridge,

All bark: New graphics techniques render the detailed textures of tree trunks.

Hot pot of innovation (clockwise from far left): Microsoft Research Asia's headquarters in Beijing; managing director Harry Shum; a student intern doing software research; Hongjiang Zhang, head of the lab's Advanced Technology Center; intern at work; a room packed with interns.

So has Bill Gates figured out China? Microsoft's chairman doesn't go that far, and his company isn't the only infotech giant to open a research lab in China *(see "Other U.S. Corporate Infotech Labs in China," p. 42)*. But he lights up when talk turns to his Beijing bonanza. "When you start a lab, you're supposed to say, 'Okay, in five years we want you to contribute,'" Gates told *Technology Review*. "These guys—nine months after they got started—had these video compression results." Those kinds of results are already setting the Microsoft lab apart from its competitors, making it a case study in global innovation. "People should pay attention to China," says Gates. "It is a phenomenon in every respect."

BEAST FROM THE EAST

Harry Shum is hungry. His entire lab is hungry. Over a catered lunch of noodles and fish in his Beijing office, Shum explains what drives his staff. "We started from nothing. The whole lab grew from this room. So I don't rearrange anything," he jokes, as if *feng shui* would matter to the world's largest software company. But just ten years ago, the area around England. "They'll often attack a problem differently from what would happen in Europe or the U.S., because they come from a different perspective. They often find solutions that are different, and in some cases different turns out to be better."

the lab was farmland. Today, Microsoft Research Asia occupies one and a half large floors in a six-story office building with a futuristic glass-front lobby. The lab has come to symbolize a city in the midst of a high-tech revolution.

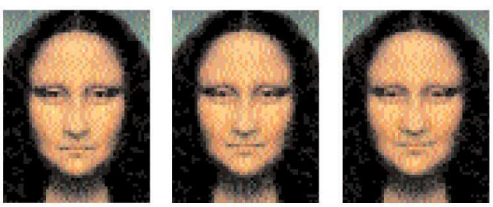
Shum himself is a vibrant mix of East and West. His English is accented but very clear. Born and raised near Shanghai, he did his graduate work at Carnegie Mellon University (he says he's "still a die-hard Pittsburgh Steelers fan") and joined Microsoft Research in Redmond in 1996. There, he became one of the company's rising stars, creating realistic 3-D graphics and virtual environments using principles borrowed from computer vision.

Two years later came the opportunity: Microsoft was starting a lab in China. The goal was to tap into the country's immense talent pool of students and scientists, including many who had emigrated to other countries but could be enticed back to their native land. And being in position to explore a marketplace of a billion people in a rapidly industrializing economy couldn't hurt, either. To lead the charge, Microsoft brought in Kai-Fu Lee, a well-known speech and multimedia expert from Apple Computer and Silicon Graphics *(see "The Founder's View," p. 38)*. Shum remembers the day well. "Kai-Fu came into my office and said, 'I'm moving to Beijing, and I'm not leaving without you,'" he says.

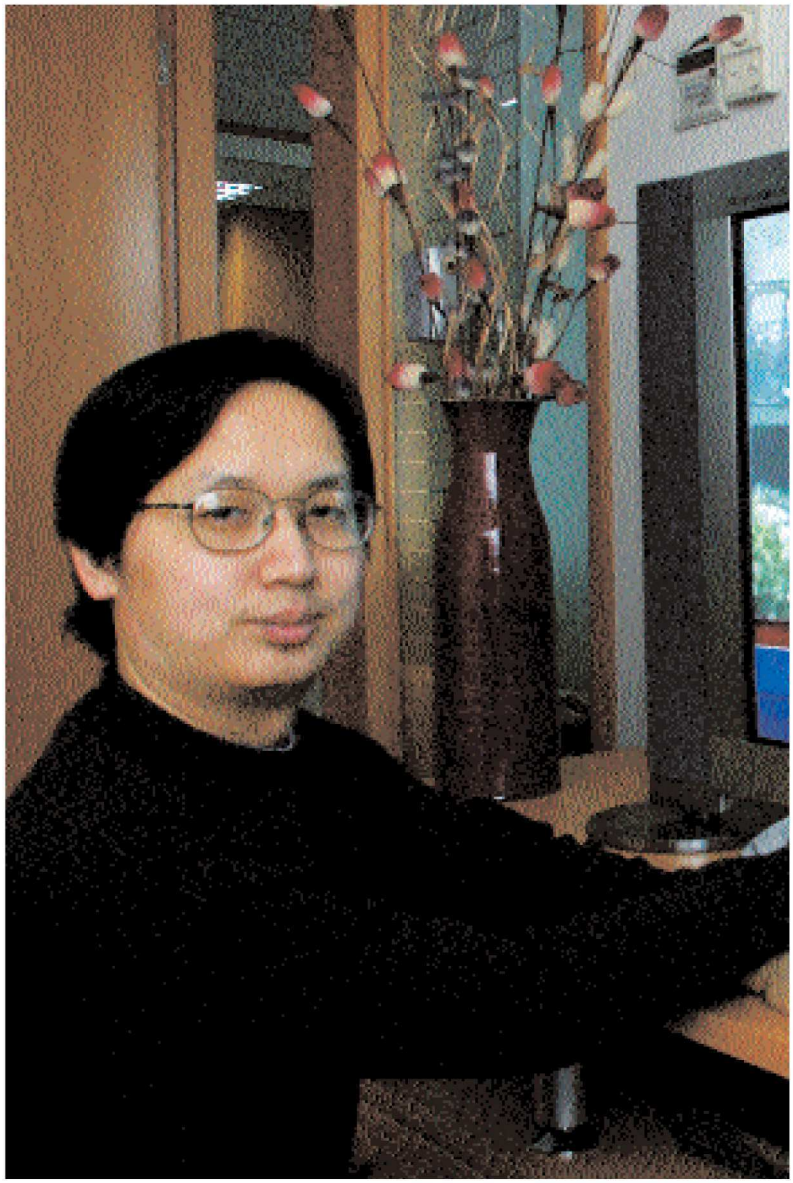
But setting up shop in Beijing was uncharted water for Microsoft Research. First, it had to gain the support of the local academic community. "One of the concerns the Chinese had was, is this some American company coming in to take the best minds from China and put them in a place where nobody ever hears from them again?" says Rashid. The central question was whether the lab would do fundamental research with publicly disclosed results or instead be an insular product development outpost. To gain its hosts' trust—and attract China's top computer scientists—Microsoft needed to establish an open environment where researchers would publish papers, meet with academics, *and* contribute to products.

To make this balance work, Lee handpicked a core team of computer scientists familiar with both the Chinese academic system and U.S. corporate culture. Graphics guru Shum knew the ins and outs of Redmond. Hongjiang Zhang was an expert in computer vision and a research manager at Hewlett-Packard Labs. And Ya-Qin Zhang, another charter employee, was a multimedia genius who went to college at age 12, became the youngest fellow in the history of the Institute of Electrical and Electronics Engineers, and was a senior manager at the renowned R&D house Sarnoff.

Lee's team first defined the research culture of the lab as decidedly Western—and open. Early on, Lee gave seminars on the importance of being straightforward rather than looking for hidden meanings, as per Chinese custom. Such seminars have since become standing-room-only events, with overflow crowds of students packing into the lab's auditorium. Researchers address their director as "Harry," not by his title, as Chinese culture would dictate. Ideas are taken seriously no matter whom they come from. And staffers have the freedom to try different approaches, even if their supervisors are unsure of the results.



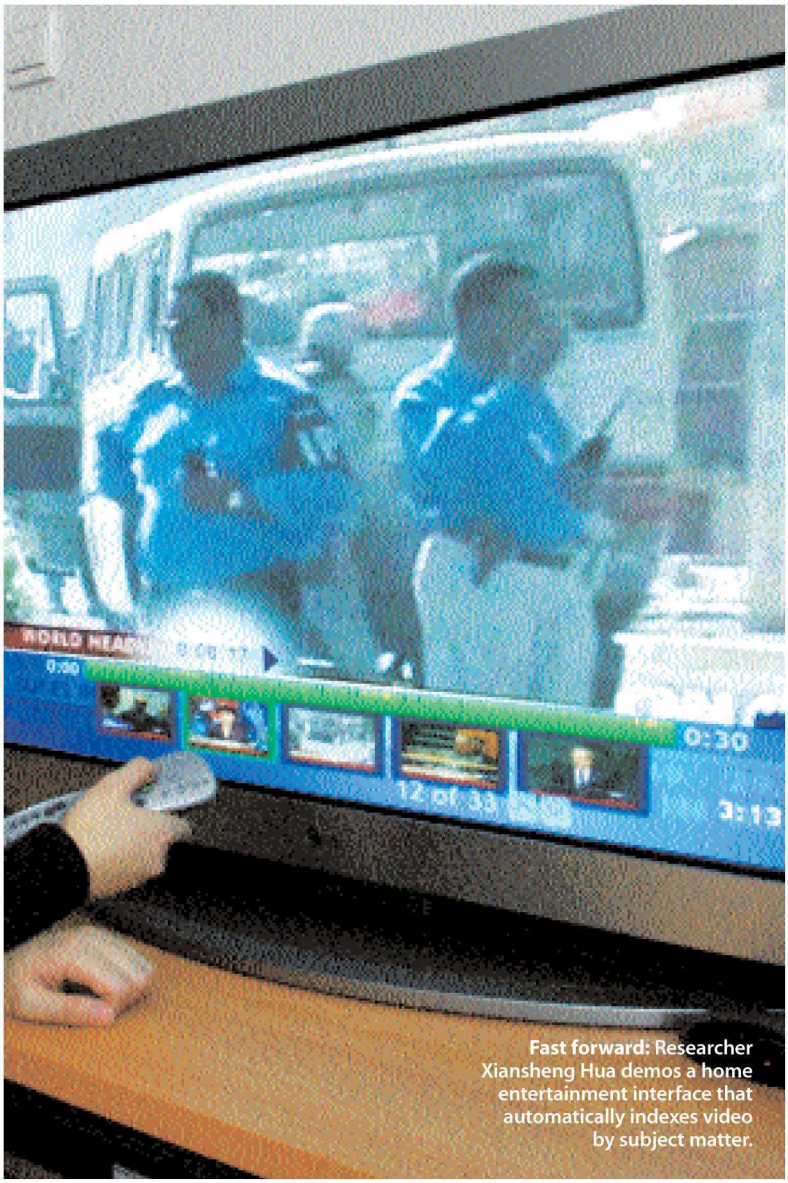
Mona Lisa smile: A computer generates new variations on an old favorite.



This culture has enabled the lab to compete on a global level. "I challenge my guys," says Shum. "I say, 'If you get to this point, do you think those MIT people can do better? If they can, maybe you should push even further.' That mentality, being the very best, is something we feel very proud of." At the same time, maintains Shum, research managers constantly think, "How is our work relevant to the company's products?"

The Beijing lab seems to have cultivated an underdog's toughness, turning its geographic separation from Redmond—a 16-hour time difference and a 10-hour plane trip—into a psychological edge. "Because we are a remote research lab, we cannot talk to product people any time we want. We can't just have a lunch meeting," says Shum. "That means we have to try twice as hard." Researchers regularly put in 100-hour work weeks. Some interns live in the office, pulling out cots to sleep on at night during the summer, when air conditioning is scarce. Not even last year's outbreak of severe acute respiratory syndrome (SARS), with its quarantines and travel advisories, could shut them down. Because of the added isolation, says Shum, "We got more work done."

The lab's bottom line: 750 published papers and hundreds of filed patents over the past five years. The key has been the mix of strong leadership and young talent, says Ted Adelson, an



Fast forward: Researcher Xiansheng Hua demos a home entertainment interface that automatically indexes video by subject matter.

expert on human and machine vision at MIT who has graduate students from the Beijing lab. "Harry has excellent taste in problems and people. He and the lab are doing some of the best work in the world," Adelson says. "They have access to the best and brightest young people in China." These young stars are lured not only by the opportunity to work with respected scientists but also by the standard of living that a Microsoft job provides; entry-level research salaries, while less than what Redmond pays, are high by Chinese standards.

Shum's staff sees mentoring students and scientists as an important responsibility, whether that means lecturing at local universities or writing articles about computer science for the popular press. "It's so satisfying as Chinese people, educated in the U.S. and overseas, to come back to the motherland," says Shum, "and to have such an impact on the younger generation."

In turn, the Beijing lab is having an impact on Microsoft's management. The lab's two previous directors, Lee and Ya-Qin Zhang, have been promoted to vice president positions in Redmond; they now shape the company's product strategy in speech interfaces and mobile wireless devices, respectively, which only adds to the lab's corporate credibility. "This lab is a place for future Microsoft leaders," says Shum, who took the reins in January. "We are training a new generation of leaders who can take a whole research team to the product level."

"THIS LAB IS A PLACE FOR FUTURE MICROSOFT LEADERS. WE ARE TRAINING A NEW GENERATION OF LEADERS WHO CAN TAKE A WHOLE RESEARCH TEAM TO THE PRODUCT LEVEL." —HARRY SHUM

The lab's achievements, however, have only increased its hunger. On a chilly evening this winter, the researchers gather for dinner at a local restaurant. It's an extravagant affair with a dozen dishes shared family-style, including homemade tofu, a whole fish, and meat and vegetables stewed by dropping hot rocks into broth. The conversation spans upcoming conferences, trips to Redmond, and Chinese culture. After dinner, many of the researchers go back to the office, while Beijing sleeps—and Redmond is just waking up.

GRAPHICS GIANTS

Baining Guo wants less talk and more action. Guo, a former Intel researcher and now Microsoft Research Asia's graphics research manager, doesn't sit for interviews. He doesn't do chit-chat. Whether the end product is a video game, a screen saver, or a personalized cartoon rendered from a photograph, he says, graphics is a bottom-line business: either it looks good or it doesn't. His group consists of 12 staff researchers and, currently, 18 students; to examine their latest results, he walks down the hall to the open area where they all work.

A pressing problem in graphics—one of the lab's standout areas—is getting computers to animate photorealistic human faces. In today's video games, "characters' expressions look fake," says Guo. "Their faces don't move believably or naturally." It's a tough problem, for instance, to get the wrinkles around the eyes and forehead to look right using conventional techniques that simply morph and stretch the features of an image.

Guo's team demonstrates a cutting-edge solution. First they take about ten still pictures of a man's face, each capturing a different expression: eyebrows raised, nose scrunched, laughing, grimacing, and so on. Then, by dividing the face into 14 regions and more than 100 "feature points"—eyelids, tips of eyebrows, corners of lips—their software blends different combinations of the photos to create more natural simulations of new expressions. The software also modulates the image from one expression to another over a few seconds. The result: the man's face goes from looking surprised to looking disgusted in a realistic way, wrinkles and all.

Unlike the techniques used in computer-animated movies such as *Toy Story*, the Beijing researchers' approach requires no manual drawing of frames. That means it could be used in a video game to generate realistic-looking faces on the fly. With some additional configuration, it could also map expressions from a user's face to a virtual character's to create a personalized avatar for a role-playing game. What's more, photos of celebrities could be animated, or reanimated. "We could make Albert Einstein say, 'I love Windows,'" Guo deadpans. His team, though, is chasing a loftier goal that could ultimately transform moviemaking: software that generates photorealistic virtual actors in real time.

That kind of commitment to more-fundamental computer science research has earned the lab the respect of the academic community. "Microsoft Research is by far the biggest contributor to graphics in the corporate world. It's a powerhouse," says Paul Debevec, a graphics expert at the University of Southern California's Institute for Creative Technologies. The Beijing lab, in particular, has achieved "some amazing results," he adds. "It's not just, 'How can we make a better Xbox?'"

But in fact, a better Xbox is ultimately part of the lab's mission. Reminders that this is a business, not a researcher's playground, are never far away. In an adjoining hallway, a large corner room has its windows plastered over with opaque sheets of paper. The sign on the locked door reads, "Xbox: Confidential." Guo isn't allowed to talk about what's going on inside. "Some of our best people work in there," is all he'll say.

THE FOUNDER'S VIEW

KAI-FU LEE founded Microsoft's Beijing research lab in 1998. Now a Microsoft vice president in Redmond, WA, Lee helps shape the company's product strategy for advanced user interfaces. He talks about how to make foreign research ventures work—for all parties.

TECHNOLOGY REVIEW: What was the key to making the Beijing lab successful?

KAI-FU LEE: To be successful in China, you have to be sincere in doing what's good not just for your company but also for China. You have to prove you're serious, sincere, and worthy of the trust of the government. It took us about two years. Initially, when we hired their best students, some professors were less than happy. But over time, as they saw these students didn't disappear into a dark room and do secret work but were frequently visiting—bringing in funding, coauthoring papers, mentoring students—they saw they were gaining more than what they may lose.

TR: How is the lab influencing Microsoft's global business strategy?

LEE: There is not a single vice president in the company who doesn't know about the stellar research going on in Beijing. There is not a single business unit that isn't using some of the lab's technology. But it's not enough to be a global company—you also need to be local. It's not appropriate to think of a country as just a place where we can go sell products and make money. We want to sell our products, yes, but we also want to be responsible citizens—not by slogan or camouflage, but sincerely. This applies to other countries as well, like India, Russia, and Brazil.

TR: Given the outsourcing flap, what will Microsoft's legacy be in China?

LEE: The usual outsourcing of development or testing really has nothing to do with Microsoft Research. It is about hiring the best minds in Asia who want to have their dream job without moving to the U.S. My dream is that the success of the Beijing lab will help Microsoft as a whole become a partner with China and make both extremely successful, and that Microsoft will really go beyond research, into products and building up the local education system and software ecosystem. There's still quite a gap between Chinese universities and world-class universities. If there are 100 PhDs whose careers we helped accelerate, there are tens of thousands of PhDs who we didn't. I think a faster acceleration in the education system can help many more people realize their potential.

MASTERS OF MULTIMEDIA

Eric Chang is a sultan of speech. He talks fast, asks lots of questions, and seems to know what you're going to say before you say it. It's a bit unnerving at first, but given his graduate training in speech recognition at MIT, it makes sense. And since computer keyboards have trouble accommodating Asian languages—thousands of characters, in contrast to a few dozen letters—part of the motivation for Chang's speech group in Beijing is to develop better interfaces for Asian users. Speech-based systems are part of Microsoft's plan to enable legions of Chinese, for starters, to access information and communicate more effectively.

Chang walks into the office of a young researcher, Min Chu, and asks her to fire up the text-to-speech demo. Chu types in a sentence—in Chinese but sprinkled with English words, as is common in technical passages and discussions. After a few seconds, the computer generates a natural-sounding female voice, which sounds perfectly bilingual as it repeats the typed sentence over speakers on the desktop.

The trick is to get the inflections, timing, and transitions from word to word to sound just right—and not like a robotic monotone. Unlike other speech synthesizers, Chang and Chu's software breaks text into different-size chunks—phonemes, syllables, or whole words—and uses a database of more than 10,000 spoken sentences to select and piece together the right sounds. This bilingual synthesizer is "really head and shoulders above anything I've heard," says MIT's Zue, an expert on spoken-language systems.

It's an example of how the lab's cultural perspective has been instrumental in solving problems. The first goal of the project was to create a Mandarin speech synthesizer for the Chinese market. "In 2001, we had our first 'Bill G.' review," says Chang. "He said, 'That's good, but I don't understand Chinese.'" That reaction from Microsoft's chairman motivated Chang's group to apply the same mathematical models to English. Because pitch matters so much in Mandarin—a subtle change of tone is all that distinguishes the word for "mother" from the word for "horse"—the system was better able to capture the inflections of English and other languages as well. Expect to see this voice synthesis software on the market in the next few years, says Chang, who recently became assistant managing director of the lab's Advanced Technology Center.

The Beijing lab is also helping Microsoft understand the Asian marketplace in more immediate consumer areas, such as multimedia communications over mobile devices. Already, there are more than 240 million cell-phone users in China alone. They tend to update their services more often than U.S. users and are more interested in gadgets generally, says Shipeng Li, head of the lab's Internet media group and another former Sarnoff researcher. "Here it's like fashion," he says.

The stylishly casual Li wears jeans and comes across as more laid-back than other researchers. His group is all about smooth—smooth video, that is. In the next room, one of Li's 20 students has set up a demo of one of the world's first video-conferencing systems that runs on a handheld computer. The

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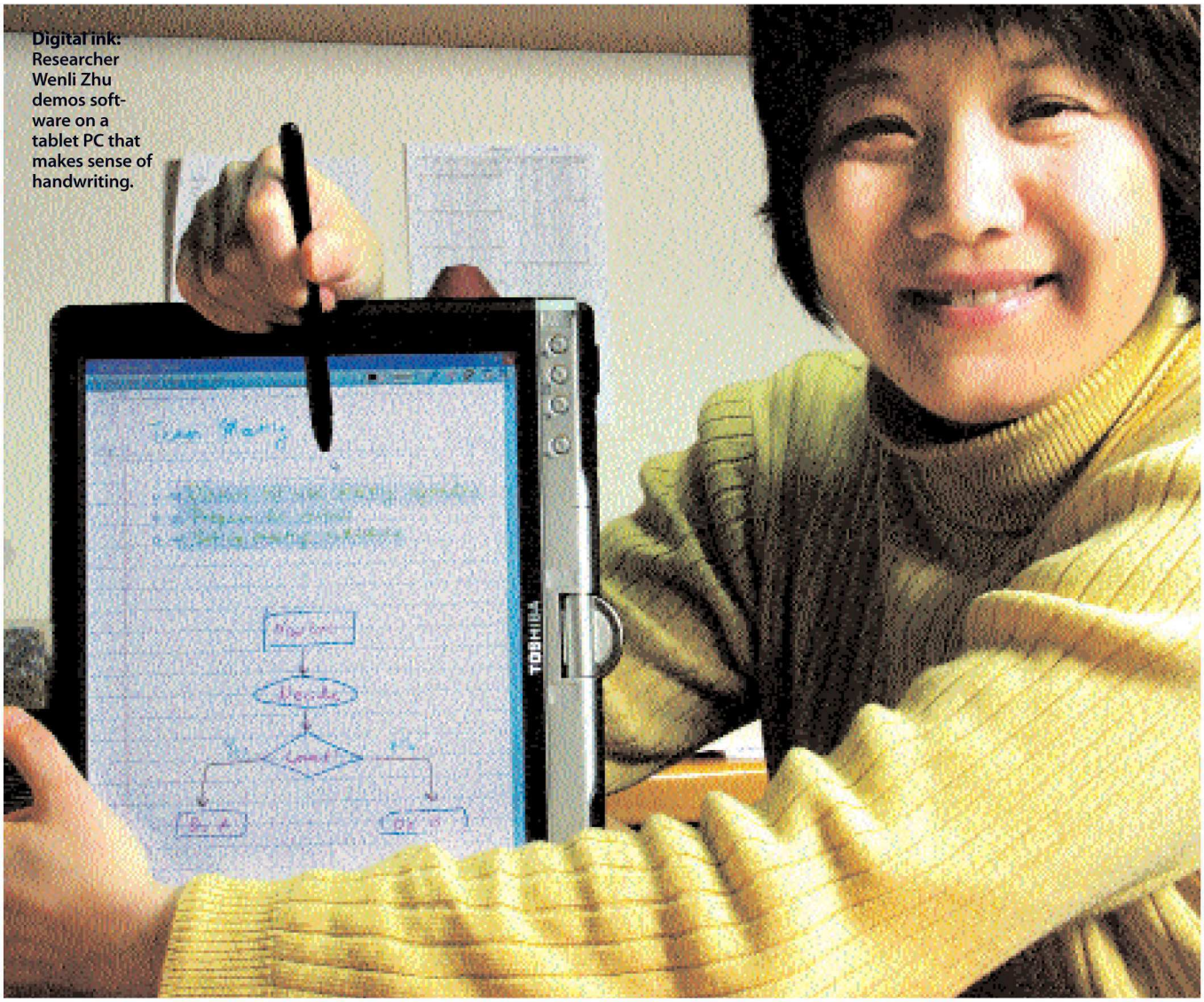


Digital ink: Researcher Wenli Zhu demos software on a tablet PC that makes sense of handwriting.

student picks up the handheld—which houses a video camera, microphone, wireless link, and data communication software—and speaks into it. His face shows up on the screen of a nearby desktop computer, which is similarly equipped. The video is encoded at 10 frames per second, enough to look fairly smooth, with an audio delay of about half a second as the researchers talk back and forth. Although the quality is lower than that of normal video, says Li, it's still far higher than that of existing handheld technologies.

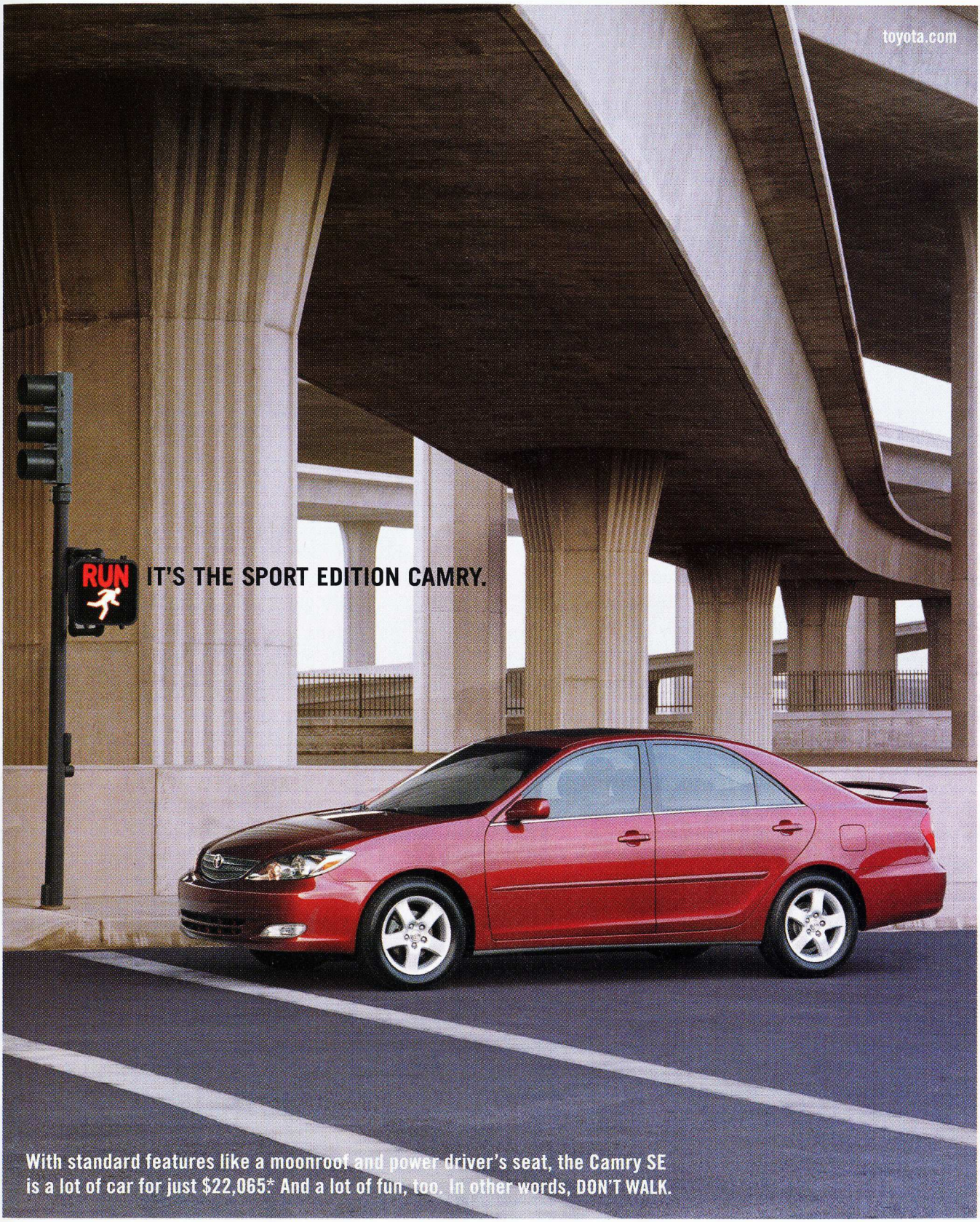
The key advance: software running on each user's computer monitors data channel conditions, takes into account what kinds of devices are being used, and efficiently compresses the video stream so that fewer bits need to be sent. Some 50,000 users have downloaded the latest prototype version of the software from Microsoft's website. If transmission delays can be reduced, Li says, handheld videophones should take off in the Asian market within three years.

But there are nearer-term applications, too. Take Web downloads of multimedia files. Researchers in Li's group are developing ways to code video so it can be sent to your desktop without the pauses, skips, and hang-ups that are all too common with today's Internet links. Li's system does this by adapting to the conditions of the data connection.

Li employs a simple analogy to explain Microsoft's advance. Imagine media content as "freight to be transported," he says. Instead of today's strategy of sending it in one big truck, which can get stuck in a traffic jam, Li's team sends it in pieces in smaller vehicles, giving higher priority to those bits identified ahead of time as being especially important. Even if some pieces get stuck or lost, on average the most important ones—those that describe the basic picture structure and how it's changing—get through.

The end result is smoother, more reliable video downloads. Using the technology, Li plays a video of singer Christina Aguilera; right next to it, he plays the same video on Microsoft's current media player. The new version is less jerky and doesn't skip. Indeed, says Li, the next release of Microsoft's media player will incorporate this smooth scheme, courtesy of the Beijing lab.

Water, water everywhere: Graphics techniques create realistic reflections in water.



*As shown. MSRP includes delivery, processing and handling fee. Excludes tax, title, license, options and regionally required equipment. Actual dealer price may vary. ©2003 Toyota Motor Sales, U.S.A., Inc.

THE GATES DYNASTY?

On the other side of the lab from Li's demo, a sea of résumés threatens to swallow up the desk of Hongjiang Zhang. Indeed, 10,000 of them have arrived in six months, he says, in application for staff openings in the new Advanced Technology Center he has been tapped to run. To help screen the onslaught of applicants, Zhang's team has resorted to administering written exams in 11 cities around China. "The biggest challenge is people," says Zhang. "We have to get the right blend of partnership, comradeship, and leadership."

Making faces: Expressions created by a computer (right), compared with real photos (left).

The Advanced Technology Center—marked by a sign in bold letters—is expanding rapidly, with a staff that grew from 20 this winter to 70 by springtime. It represents the next step for the lab, one in which Beijing's research results will be more directly transferred to products. The goal: to speed up the process of feeding new technologies back to the mother ship.

The center is Zhang's baby. As a researcher, Zhang created software that looked at pictures and could identify which were visually interesting and which were not—useful for automatic video editing. Now, leaving research behind, he is looking at the bigger picture of the lab and trying to identify those technologies that are most promising for Microsoft's product groups. "What is the return from investing heavily in long-term research?" he asks. "The mission of the center is to answer that question."

Zhang reveals a hint of nostalgia as he discusses the center, which was launched in November 2003 at the five-year anniversary of Microsoft Research Asia's opening. At the ceremony, he says, the company's research head, Rick Rashid, recounted the lab's accomplishments and gave his heartfelt congratulations to its leaders in front of Microsoft's higher-ups. "Looking around the room, we had tears in our eyes," says Zhang. "We thought, 'This is a dream come true. We made history.'"

But now, Zhang says, it's time to start making the company's future, by developing new products that will be used by a wider swath of society. Instead of sending research managers across the Pacific to meet with product people—a process that Zhang says "will not scale up"—the Advanced Technology Center's staff will do initial product development in Beijing. Their proximity to the research teams will make it easier to determine which technologies are ready for products. At the same time, they will visit Redmond regularly, staying close enough to product teams that they can advise researchers about real-world issues. That's a way for "research to create value for the company," says Henry Chesbrough, an expert on technology strategy and management at the University of California, Berkeley.

The question for Microsoft is whether the Beijing lab can keep its close-knit researchers focused on long-term issues, while at the same time accelerating near-term product development plans. Nobody thinks this balancing act will be easy. "Part of the price you pay is, people begin to ask you for low-hanging fruit," says MIT's Zue. "Your success can easily turn into a curse if everybody's asking you for something they need six months from now."

If this were the United States, that might be the most daunting challenge the lab faced. But this is China. To remain productive, Microsoft Research Asia will also need to nurture its relationship with government officials and academics, so that it benefits not only Microsoft but also its host country. Therein lies a source of tension. Local graduate students say it is their dream to work for Microsoft. But go higher up the ranks of Chinese academia, and there is talk of a dark side. "It's a shame the government and university authorities allow such a waste of talent," says Hongfei Wang, a professor at the Chinese Academy of Sciences' Institute of Chemistry. "These poor graduate students actually don't have better choices. But by doing work on company projects, their opportunity for intellectual growth is greatly diminished."

Indeed, Microsoft's legacy in China may ultimately depend on whether the company Bill built is able to augment opportunities for Chinese citizens in general. Strengthening the educational system, providing technical training for young people, fostering local software companies, and promoting economic growth are a good start—and smart business—for what might one day be called the Gates dynasty.

AT THE END of another long workday, Harry Shum gets into a company car that will take him home to a subdivision on the outskirts of Beijing. The lab's managing director checks his e-mail on a wireless handheld and then uses it to call home. He's meeting his family for dinner; this will be the first night in a month that he hasn't worked late. Beijing is peaceful at night, quiet. But things are changing fast. "This highway wasn't even here five years ago," Shum says. As he looks down this new road, he is already thinking about tomorrow, fighting the traffic in his mind, figuring out how to take his lab to the next level.

Gregory T. Huang is a *Technology Review* associate editor.

OTHER U.S. CORPORATE INFOTECH LABS IN CHINA

ORGANIZATION	ESTABLISHED	CITY	STANDOUT TECHNOLOGIES
IBM China Research Laboratory	1995	Beijing	Speech interfaces for telephones, machine translation, mobile devices, e-commerce
Intel China Research Center	1998	Beijing	Speech recognition with visual cues, machine translation, machine learning, advanced software compilers
Bell Labs Research China	2000	Beijing	Data networking, communications, optics
Motorola China Research Center	2000	Shanghai	Speech and handwriting recognition, natural-language processing, Internet data processing

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Skype beyond the hype

You've probably heard all about Internet telephony, but chances are you still aren't using it to make phone calls. That may be about to change. The creators of peer-to-peer software that lets people share and copy music files are finally making Internet calling free and easy.

BY ROXANNE KHAMSI

ILLUSTRATIONS BY LARA TOMLIN

MY TRANSATLANTIC CALL with my little sister at Smith College in Northampton, MA, starts with her recurring complaint about the campus food. This week, it seems, there's a shortage of fresh fruit. Normally, as the long-distance seconds tick by, I'd be tempted to ask her about more serious issues. But this time I'm happy to listen: our hour-long call, placed over the Internet from my computer in Riga, Latvia, to her computer in Northampton, is using a free program called Skype and is costing us nothing. ■ When I start up Skype to call my sister, the software links my PC with the computers of other Skype users who also happen to be online. In this case, one of them is my sister, 6,500 kilometers away. Our voices are broken into digital packets that hopscotch from computer to computer until they reach their destinations, where they're reassembled into astonishingly clear audio.

The peer-to-peer strategy used by Skype is very similar to that of the Internet file-sharing systems, such as the original Napster, that have become the bane of the music industry. Indeed, the creators of Skype—Niklas Zennström of Sweden, Janus Friis of Denmark, and a set of expert programmers in Estonia and elsewhere—are largely the same team that unleashed Kazaa, the music-sharing program perhaps most loved by music swappers and most reviled by music corporations. So it's only natural that Zennström and Friis, who have given away more than 10 million copies of their new software to users in more than 170 countries since launching Luxembourg-based Skype Technologies in August 2003, would be anointed by some as Davids aiming their high-tech slingshot at the Goliaths of the telecom world.

But in reality, the two entrepreneurs and their programmers are hardly radicals out to destroy the telephone as an instrument of profit. Despite their nonconformist markings, they're simply ambitious businessmen intent on changing the economics of making a phone call. Other companies such as Net2Phone have been routing calls over the Internet for years *(see "The Internet Phone Booth," p. 47)*, but most such services still depend on centralized computer servers to direct calls and track usage and must charge accordingly. Skype's leaders, on the other hand, believe they can afford to give away their software and let users call each other free, confident that customers will pay for the additional services they plan to introduce, such as voice mail. And there is another reason for their generosity: they have no complicated infrastructure to build and maintain. They simply use the Internet.

So far Skype has about 4.5 million registered users, but its ability to expand its base of customers indefinitely simply by handing out more copies of its software has many in the information technology and investment communities watching it closely. In March, Skype raised $18.8 million in venture funding from investors such as Silicon Valley's Draper Fisher Jurvetson and Geneva, Switzerland-based Index Ventures. German electronics giant Siemens says it will launch a line of cordless phones in September that incorporate Skype's software, and wireless Microsoft Pocket PC personal digital assistants can now run a stripped-down version of the software that turns them into mobile Skype phones. Both developments untether Skype users from their PCs.

No one expects that free peer-to-peer telephone service will eat into traditional calling as rapidly as software like Kazaa has deflated the retail music business. For one thing, most current Internet calling technology still requires users to buy and install special modems and adaptors. But Internet telephony will catch on "quicker than most people realize," predicts Randolph May, senior fellow and director of communications policy studies at the Progress and Freedom Foundation, a Washington, DC, think tank focused on the digital revolution. Indeed, once consumers have experienced the surprising sound quality of Internet voice calls, not to mention the pleasure of getting no bills—or very low ones—they may find that old-fashioned dial tone harder to listen to.

Zennström (left) and Friis knew that conventional phone companies face huge marketing and operating costs. But by clever use of peer-to-peer software, they realized, Skype could outsource the entire business of running a telephone network to its own users.

EAR-TO-EAR COMPUTING

A few days after the call with my sister, I'm sitting in a small set of offices in a renovated Soviet-era factory in Tallinn, the capital of Estonia. I'm visiting Ahti Heinla and Jaan Tallinn, a cheery and startlingly tall pair of programmers who helped Zennström and Friis by doing much of the coding behind Kazaa and were called in again to help complete Skype. Heinla's personal office is hardly a dot-com wonderland of multigigahertz processors and fancy flat-screen displays: it contains just one standard desktop computer.

"I'm thinking about buying a laptop," Tallinn says with a capricious smile. Heinla doesn't have a laptop yet either, but he does say he bought his first home computer a few months ago. He didn't even have a cell phone until two years ago—shockingly late in this Baltic state where cell phones are next to ubiquitous. These guys firmly oppose investing in unnecessary equipment. "We're into technology, but we're not gear freaks," Heinla asserts.

The aversion to buying your own hardware when you can use someone else's is at the core of Skype's strategy. Both Zennström and Friis had been working for a Swedish telecom company when they decided in 1999 to break free and try something more daring. They settled on creating a peer-to-peer file-sharing network, turning to the Estonian programming team to come up with a system that would allow users to find files such as MP3 songs on one another's computers, even if no single machine contained a master list of the files' locations. In other words, Zennström and Friis wanted to let users exchange music but didn't want to maintain a centralized server to manage the network.

Within months, the Estonian programmers had found an approach that fit the bill, and their system, Kazaa, turned into a major smash: the free software has been downloaded more than 300 million times. But it also led to legal headaches for Zennström and Friis, as music publishers tried to fight back with piracy lawsuits. The pair eventually sold Kazaa in 2002 for an undisclosed sum. Their next big career move was logical. They wanted to create a service that would also be peer-to-peer but this time find an area of unquestionable legality. Their choice: Internet telephony.

Zennström says he had already "learned how telephone companies work, and that in their business model it's extremely costly to acquire customers, and secondly very costly to operate each customer in terms of the billing system, customer service, and

network." Recruiting members into a peer-to-peer network and sending calls through members' computers, he and Friis realized, would mean they wouldn't have to build their own network, or even a billing system, since the calls themselves would be free.

Skype might operate much like Kazaa, but there is a twist. "Kazaa was a much simpler technology than Skype," says Zennström. "With Kazaa, you're not usually searching for something that is unique. You're searching for things that are usually duplicated"—like a popular Madonna song owned by hundreds of people on the network. With Skype, however, "you need to find a unique person. If you want to make a call to me, for instance, then you need to find me and not someone who's similar to me." This time around, there would have to be a master list—and the trick would be creating it without resorting to an expensive infrastructure of centralized computers.

OUTSOURCE EVERYTHING

Skype's solution is dubbed Global Index. This bit of software tells computers in the peer-to-peer network how to communicate with hubs known as "supernodes" in order to find the locations of people being called. With Kazaa, similar supernodes—which are simply PCs randomly selected from among the most powerful computers that happen to be online at a given moment—play a crucial role in relaying file requests. But with the Skype technology, the supernodes can also talk to each other and collectively store a complete, up-to-date directory of every Skype user online. Calls move seamlessly from computer to computer even as supernodes go online and offline without notice. By clever use of software, Skype can outsource the entire business of running a telephone network to its own users.

Skype's base of users is still tiny compared to the market for traditional phone service. So far, subscribers can use the network only to call each other. And the software doesn't come with the kind of service and support guarantees that many users, especially in the business world, expect. But Skype may not need business customers in order to thrive. If average users get hooked on the free calls, they may not mind paying for the premium services—including voice mail and the ability to call conventional phones—that Zennström hopes to roll out later this year. And while those services may force Skype to adapt the way its system works, its costs will likely remain lower than those of its competitors.

Meanwhile, don't expect traditional telephones to disappear. The shift toward Internet telephony will more likely resemble the transition from fax to e-mail as the preferred way to send text quickly, Zennström predicts. "You still have the fax machine, but you're not using it as much as you used to," he says. In fact, he sees a practical benefit in Skype for the existing telecom industry, if consumers interested in making calls over the Internet flock to high-bandwidth cable and DSL services. "There is a huge broadband market potential for telecoms to go after, which will work well with our offering."

Free phone calls, high-flying startups, soaring demand for telecom capacity—the promises might sound a bit familiar. But Skype may be the company that finally delivers on the hype. TR

Roxanne Khamsi is a former editor at the *Baltic Times* and covers technology, business, and culture from her base in London.

The Internet Phone Booth

AS EARLY AS the mid-1990s, PC owners could use software from companies such as Newark, NJ-based **Net2Phone** to make low-cost calls over the Internet using their home or office computers. But until recently, Internet calling has been more of a curiosity than a serious rival to the traditional telephone network, frequently suffering from poor sound quality and spotty connections. With today's faster Internet service and new hardware that can send Internet calls through regular phone handsets, however, Internet phone connections can be better than conventional ones. And that's leading to the first real surge of interest in Internet telephony.

The key to Internet calling is that it's cheap—for both the provider of the service and the consumer. Voice signals are broken into digital bits and shipped over the public network in the same form as e-mail, Web pages, and streaming audio or video; hence the industry term "voice over Internet Protocol," or VoIP. Because it's generally cheaper to send chunks of voice data on random paths through the Internet than to set up a dedicated telephone connection, voice-over-IP companies can charge less. Rates for international calls can be a fifth of those charged by traditional international phone services.

While Internet telephony startups like Skype have garnered the most attention, the traditional telephone companies are also busy getting in on voice-over-IP technology. In January, New York, NY-based **Verizon** announced that it will gradually replace traditional switching equipment with VoIP switches throughout its local and long-distance networks. **AT&T** of Bedminster, NJ, meanwhile, has rolled out a consumer Internet phone service called CallVantage in New Jersey and Texas, with plans to expand to 100 metropolitan areas by the end of 2004. Customers of the service plug their phones and their computers into special adaptors that connect in turn to their DSL or cable modems; to make calls, they simply pick up the phone. Among the other leading VoIP providers: **deltathree** (New York, NY), **Dialpad Communications** (Milpitas, CA), **8x8** (Santa Clara, CA), **Voiceglo** (Fort Lauderdale, FL), and **Vonage** (Edison, NJ).

Plenty of roadblocks remain before Internet calls become routine, however. For one thing, regulators at the Federal Communications Commission continue to debate whether Internet phone services should be subject to the same fees and taxes as traditional phone service or permanently classified as data services, which haven't been taxed so far. Their decision could drastically change the economics of the industry. Then there are the questions of how to locate someone calling 911 over the Internet—a federal requirement for other kinds of phones—and how the FBI will wiretap Internet calls.

While most potential users of Internet calling won't stay awake worrying about these issues, they will want to shop carefully if and when they finally decide to make the switch. Only a few companies will survive the inevitable attrition among the dozens now doing battle. Those that do, however, promise to give consumers their first realistic alternative to traditional phone service. WADE ROUSH

Where's the Beef from?

In the wake of the mad-cow-disease scare, the meat industry is looking to everything from retinal scanning to DNA testing to better track the nation's food supply. But is the technology up to the chore of making sure your dinner is safe to eat?

BY DAVID TALBOT | PHOTOGRAPHS BY GREG MILLER

Walk into a Jusco supermarket in Yamato, a small city near Tokyo, Japan, and you can glimpse the future of meat. In addition to a conventional bar code, each steak package sports its own ID number. Type the number into the computer sitting on a nearby table, and up pops information about the cow the steak came from: a scanned copy of its negative test result for mad-cow disease and, in case you are interested, its breed and sex, its date of slaughter, and the name of the producer. At some Japanese meat-counter displays, you'll even see a picture of the family that raised the animal.

All this information is available because the steaks come from Japanese cattle that have been individually tracked from birth, generally with radio frequency identification (RFID) tags; each of the cows has an ID number correlated with a database entry that documents its birth date, medical history, and movements from feedlot to slaughter, and the results of mandatory mad-cow tests. At slaughter, the ID numbers, and all data linked to those numbers, are passed on to individual boxes of meat.

It's the future of the meat industry, perhaps, but still a far cry from how things are done in the United States, where few of the 96 million cattle scattered across 800,000 ranches and feedlots are subject to comprehensive electronic digital record keeping. Indeed, fewer than 5 percent are electronically tracked from birth to slaughter, and even then, the identifying information is generally lost during the processing of the meat. "Certainly, at the steak level, you literally don't have any idea of where that animal might have come from," says Geoffrey Dahl, a professor of animal science at the University of Illinois at Urbana-Champaign.

All that could be about to change, however, as the U.S. meat industry faces immense pressures to update its antiquated practices. The wake-up call was the finding of mad-cow disease in Washington State late last year. The federal government took four days to determine where the sick Holstein came from, which didn't exactly inspire confidence that future outbreaks—whether of mad cow or any other disease—could be readily contained. The scare decimated the $3.3 billion annual U.S. beef export market, as more than a dozen countries—the biggest in terms of consumption being Japan—slammed their doors shut to U.S. beef.

In response, the U.S. Department of Agriculture is pressing beef producers to voluntarily adopt new technologies so that by next year, any individual animal can be traced back to its birthplace within 48 hours. A pending bill in the U.S. Congress would mandate a still undefined system to electronically track cows from birth to slaughter. Meanwhile, Japanese and other foreign buyers are demanding proof that all cattle have been tested for mad-cow disease before they reopen their markets to U.S. beef.

The U.S. meat industry is consequently facing an extreme infotech makeover involving everything from RFID tags to retinal-scanning identification to global-positioning tracking technology—and even DNA testing. It's a makeover that's long overdue. "Today, a lot of this is done by gosh and by golly," says Gary Acromite, chief information officer at Greeley, CO-based Swift, the nation's third-largest meatpacker. "The traceability process is intended to take an old, old, old, old process that is very manual and modernize it with emerging technologies."

The coming rush to trace meat could provide benefits that would extend far beyond ensuring that beef is safe from mad-cow disease. Indeed, for many sectors of the $95 billion livestock industry—not just beef but pork, lamb, and other meats—better tracking could provide a way to document to consumers that products are from animals raised on, say, organic feed, or that they have been tested for a wide variety of diseases. Moreover, once the meat industry gains the ability to track animals from birth to market, it will be able to determine which produced the best cuts and use that information to optimize breeding, veterinary care, and feeding practices. "From my point of view, it's a no-brainer," says Ray Goldberg, a professor of agribusiness at Harvard University's John F. Kennedy School of Government.

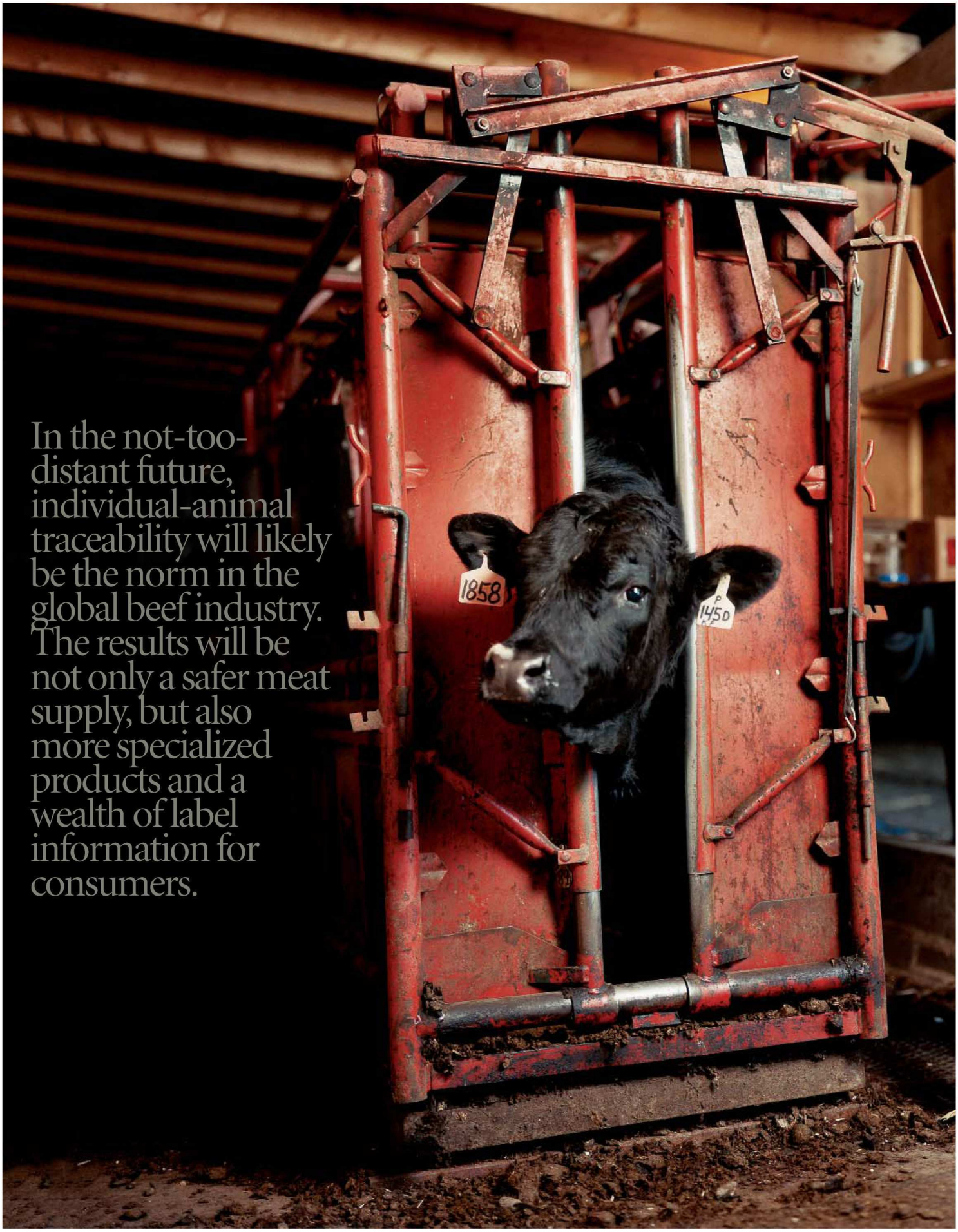
EYES WIDE OPEN

Bringing the digital revolution to the farm is a daunting chore. For starters, most U.S. cattle producers are still mom-and-pop operations selling fewer than 500 calves every year. Margins are slim, and farmers tend to be skeptics about new technology. "Despite what Congress is saying, this is not something where we wake up one morning and say, 'Wow, why don't we roll out traceability to 800,000 beef producers across the country?'" says Mark Armentrout, chief operating officer of AgInfoLink, a Longmont, CO, company that sells radio frequency identification tags and software.

The seemingly Herculean task is, however, somewhat eased by the fact that a few large corporations dominate the meat-processing business. Three companies—Tyson, Cargill, and Swift—together process more than two-thirds of U.S. beef. And the lessons from the mad-cow outbreak in the United Kingdom during the 1980s and '90s are never far from the minds of officials at these firms. The British outbreak infected 200,000 cows and resulted in the precautionary killing of some 4.5 million more. Following reports of deaths from the human version of the disease, called variant Creutzfeldt-Jakob disease, markets throughout the world closed to British exports. Ultimately, the U.K. outbreak resulted in the deaths of some 150 people, and some export markets remain closed to U.K. farmers to this day. U.S. meat producers are also well aware that what finally quenched the epidemic and reassured consumers was not only increased testing and a ban on dangerous feeding practices but a rigorous tracking system. These days, every cow raised in the United Kingdom is tracked for life with a bar-coded "passport."

JEREMY SUTTON-HIBBERT (SUPERMARKET AND LABEL)

Freshness data: At a Jusco supermarket near Tokyo, a consumer enters a code number from a steak package label (below) to get information about the source animal.



In the not-too-distant future, individual-animal traceability will likely be the norm in the global beef industry. The results will be not only a safer meat supply, but also more specialized products and a wealth of label information for consumers.

Digital barn: Ed Greiman, an Iowa feedlot owner, is one of the few who use radio frequency ID tags on their cattle, including this cow in a neck hold for routine testing.

The United States is still far from having such a system in place. But large meat-processing companies like Swift are getting started. Swift's novel approach is based on retinal scanning to record the unique vascular patterns in cows' eyes. A handheld device is placed in front of the animal's eye, and a few seconds later, the pattern is recorded and the animal positively identified. The cows don't mind: "The first thing they do is they open their eyes real wide. They kind of look at it and stop," says Bruce Golden, CEO of a small Colorado company called Optibrand, which developed the system and supplied it to Swift.

The retinal scanning is used on a portion of Swift's own feedlots to keep track of the animals it raises—roughly a third of the 5,400 cattle it slaughters every day at its Greeley packinghouse. In a number of ways, the technology offers advantages over RFID tags, which occasionally get lost, can be switched by unscrupulous producers, and pose at least some risk of winding up stuck in a steak. Retinal scanning allows Swift to document where its cows were raised, and though it is just one step in tracking each animal's medical history, it is already giving the company a marketing edge. "Even traceability back to lots of 20 or 30 animals has helped us in the marketplace," says Swift's Acromite.

But identifying an animal is only the first part of a tracking system. The real benefit comes from building a database that contains information such as birth date, identity of the animal's "sire" and "dam" (as parents are known), its weight at various stages of life, dates and descriptions of medical treatments or hormone injections, and sales prices at auctions. "The real key here is that we are betting that in the not-too-distant future, the consumer, the government, and the world will require individual-animal traceability," Acromite says. And while there's no clear technology mandate or standard just yet, he says, the company is also integrating RFID tag readers and bar code scanners into its system in order to be ready "no matter what the feedlot guy, the government, or the industry throws at us."

As a final touch, the handheld scanner developed by Swift and Optibrand includes a GPS receiver. Eventually, if the technology becomes widely used, an animal's location will be logged in the database each time its eye is scanned. GPS coordinates could be correlated with locations such as the ranch where it was born, the feedlot where it grew up, any auction houses it might have passed through, and the slaughterhouse. This location information would be critical to rapidly identifying the herd mates of a sick animal. Consider what happened in the case of mad-cow disease in Washington State. An inspector noted that an animal appeared sick when it arrived for slaughter and pulled it out for testing. When the test came back positive, it took four days to learn where the sick animal came from and to identify its herd mates—not all of whom were accounted for. But if a sick cow shows up at Swift's gate, and it's been tracked from birth, such epidemiology could be accomplished almost instantaneously.

PORCINE PRIVACY?

Though retinal scanning may be an important piece of the meat-tracking puzzle, it has an obvious disadvantage: the eye needs to be connected to the rest of the animal. Once the animal is cut apart—"disassembled," in industry parlance—the retinal scan is no longer useful. Neither, for that matter, is an RFID ear tag.

The one surefire identifier is DNA, which can be used to trace any animal part anywhere in the production process—and let consumers know where, exactly, their dinner came from.

This advanced, and still pricey, technology is finding its initial applications in North America's $13 billion pork industry. Though pork producers might not have to worry about mad-cow disease—there is no equivalent mad-pig disease—they face their own safety worries, as well as growing consumer demand for products from pigs raised in healthy and disease-free environments. For producers hoping to market their products as premium pork, it is critical to document just where the meat came from.

Maple Leaf Foods—Canada's largest producer of pork—plans by this November to market pork products that are tracked by the industry's first DNA-based meat-tracking technology. It includes a DNA test and a database that will allow pork products to be conclusively traced from a store shelf back to their origins. Initially, the products will be sold in Japan, where consumers have proven willing to pay extra for reliable information on meat origins. At a current cost of 40 Canadian dollars per test, the technology is clearly not suitable for routine testing of packages of meats, but it could be used to spot-check shipments of pork to assure consumers and stores that they originated on Canadian farms and are safe. "We want to reposition the Canadian pig industry in terms of food safety. We can prove that this piece of meat in Tokyo came from Canada, and from Maple Leaf, and from a certain food production system," says John Webb, the Toronto-based company's director of genetics and science.

Eyes have it: A hand-held device checks a cow's unique retinal blood vessel pattern.

The technology, developed by Pyxis Genomics of Chicago, consists of a simple test that determines the presence of a set of genetic markers known to be common to a mother and all her offspring. Once a mother's DNA fingerprint is in a database, a tissue sample from a piece of meat can be tested to see if it matches. It's a technology particularly well suited to the arithmetic of pig breeding. A sow can produce 50 to 70 piglets in a lifetime, so a single blood sample from a mother pig provides a way to conclusively verify the source of an enormous quantity of chops, loins, and bacon.

A key element of the Maple Leaf system is a database under development by IBM Canada. At first, the database will contain limited information; if a sample is tested and a match found, it will simply show that the pork came from the offspring of a particular sow at a certain Maple Leaf supplier's farm. But the database is being constructed to handle more detailed information about pigs, such as their birth dates, weight gains, medical treatments, and breeding history. "It's extremely scalable, so all the pigs in the world could be in this database, and it still could run quickly," points out Susan Wilkinson, who heads the Maple Leaf database project as an associate partner with IBM's business consulting service in Toronto.

Maple Leaf says it hopes to eventually use a single DNA test that can be used to not only trace meat but also screen it for pathogens like *E. coli* and salmonella. "That's the dream ticket, and a lot of people are working on it," Webb says. He's optimistic that such a test will be available in five years, helping to enhance the safety of pork supplies. "DNA is very much the platform for the future," he contends.

But while DNA testing is an exciting prospect, it remains a niche opportunity for the marketing of high-end food products. For now, it's far too expensive to play a role in most of the U.S. and Canadian pork industry, never mind at North America's 800,000 cattle farms. And even for more mundane and readily available technologies like RFID tags, the gap between optimistic promises and the realities on the farm and feedlots means improving the safety of the nation's meat supplies will be a stiff challenge.

FEEDLOT VISIONARY

Consider the day-to-day realities faced by Ed Greiman. Greiman owns a modest feedlot in the northern-Iowa town of Garner that each year fattens 2,400 cattle for slaughter. In his barn, an eight-year-old Fujitsu laptop shares a wooden shelf with assorted hand tools. Duct tape binds the computer's cracked case, and plastic welding compound keeps the display from falling off. But the machine flickers to life, and AgInfoLink's cattle management program, called BeefLink, lights up the screen. The program helps manage the growth and health of individual animals, identified by means of RFID tags on their ears. With the program's aid, Greiman can do things like provide custom medical treatment and cull poor weight-gainers early.

One late-winter day, Greiman opens a metal gate and wades into a cattle pen to demonstrate the benefits of the technology. In the pen, 80 skittish cattle stomp on cornhusks as they go about their life's work: munching on a mixture of hay, cow corn, and a high-calorie, high-protein yellow slurry. Greiman corrals a brown-and-white cow through a steel cattle chute then yanks a lever that pins the animal's neck between two steel bars. Then he waves an RFID tag reader past a quarter-sized white tag on the cow's ear.

PATRICIA BARRY LEVY

Front-line laptop: In an Iowa barn, Ed Greiman's battered computer holds a database on his cattle. Tags on the animals' ears are read with an RFID tag reader that sits to the left of the laptop.

This one is number 1565, and the database tells a story that might otherwise have gone unheard. On November 30, her temperature was a slightly feverish 39.4 °C, and she was given some antibiotics. On December 2, it was still 39.4 °C, and she got more antibiotics. Still later in the month, the fever persisted. Most troublesome to the bottom line, though, was that the ailing number 1565 was simply not gaining weight. It happens all the time: some animals are better suited for feedlot life than others. Any additional investment—antibiotics, hormones, yellow slurry—won't produce a higher carcass weight. The ear tag helped Greiman make a clear decision: animal number 1565 would be on the next truck to the packinghouse.

But Ed Greiman is also frustrated by what happens on either end of his process. Fewer than 10 percent of the 990,000 Iowa-raised beef calves supplied to feedlots like Greiman's each year carry any individual records. That makes it nearly impossible for Greiman to custom-order calves with consistent or predictable genetics. Instead, he must work with whatever walks through his gate. On the outgoing side, the data Greiman dutifully collects dies along with the animals inside a Tama, IA, slaughterhouse. Without a large-scale, integrated network for gathering genetic and disease information on meat throughout the food chain, well-intentioned efforts like Greiman's are little more than duct tape on a food-safety disaster waiting to happen.

It's a long way from the realities of Garner, IA, to the high-tech Jusco supermarket in Japan. But today's meat industry is increasingly global, with shoppers often buying products raised and processed halfway around the world. Those global consumers, in turn, are increasingly concerned about mad-cow disease, bacterial contamination, and other safety and quality issues. In short, consumers want to know where their meat is from, and they want guarantees that it is safe. And the industry faces looming regulatory and market pressures to adopt information technology.

As the information age dawns on U.S. meat producers—whether modest operations like Greiman's or huge corporations like Swift—the differences between how things are done in Iowa and Tokyo could eventually dissolve. So while high-tech tracking like Jusco's might seem exotic to U.S. consumers, it may be coming to a supermarket near you. And if it does, a family buying a steak might see a photo of a smiling Ed Greiman, as well as a certificate documenting that its dinner is safe.

David Talbot is a senior editor at *Technology Review*.

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FROM THE EDITORS OF TECHNOLOGY REVIEW

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SPINOFF SPOTLIGHT

Micromanaging Money on the Web

PEPPERCOIN IS POISED TO TRANSFORM THE BUSINESS OF ELECTRONIC PAYMENT, THANKS TO SOME FANCY STATISTICAL FOOTWORK

It's simple mathematics, says Silvio Micali. Sitting in his office at MIT's Laboratory for Computer Science, Micali is explaining how he and fellow MIT computer science professor Ron Rivest set out to create a new system for electronic payments with their startup, Peppercoin. Micali is an expert on cryptography and holds more than 20 patents. Rivest is the "R" in the RSA encryption system that allows people to make payments securely online. So this team has credibility. Their idea: make it profitable for publishers, music distributors, and other media companies to sell Web content and services at low prices by using statistics and data security to cut the overhead cost of each transaction.

Founded in late 2001, Waltham, MA-based Peppercoin focuses on micropayments: electronic transactions of a dollar or less. Why the fuss over digital pocket change? Because more and more companies are looking to charge for what they provide on the Web. According to Avivah Litan, a Gartner Research analyst specializing in online financial systems, 40 percent of online companies have content they would try to sell, instead of give away, if they had a viable micropayment system. Apple's widely publicized launch of a music downloading service that charges for individual songs is the latest example of the trend. "The Internet is in critical need of a new lightweight business model—something between free access and credit card payments," says Greg Papadopoulos, chief technology officer at Sun Microsystems and a member of Peppercoin's technical advisory board.

But to become profitable, online-payment companies must gather a critical mass of merchants and consumers. The history of e-commerce is littered with micropayment startups that failed to find customers—Digicash, Cybercent, and Flooz, among others. PayPal, the online person-to-person payment company, succeeded (albeit not with micropayments, yet) because it provided easy-to-use systems to a huge audience—namely, customers of online auction house eBay. And pay-for-content systems from Cologne, Germany-based Firstgate are gaining popularity in Europe. As micropayment systems become easier to use, analysts say, the market will open up. "At the core, we believe we have the right way to process all these transactions," says Perry Solomon, Peppercoin's CEO.

PEPPERCOIN

The problem with micropayments has always been that processing individual transactions is too expensive to make it worth the trouble. When a consumer uses a credit card over the Internet, the seller's bank collects a roughly 25-cent fee, plus a percentage of the sale. Merchants aren't willing to eat this cost for small-ticket items, because it cuts too deeply into profit margins. Nor are consumers willing to pay such a premium. An alternative is a subscription, with one fee covering multiple sales. This is more manageable, but the customer must commit to buying a series of items from the merchant—say, by paying up front for 10 archived articles. And the merchant must keep track of each customer's credit.

Peppercoin's approach is novel, says Micali, because it consolidates money transfers and requires no agreements between merchants and customers. Say you want to download a song for 20 cents. Click on it, and you receive your music—but more than likely, no money changes hands right then. In fact, Peppercoin transfers money on only a small fraction of a given merchant's trans-

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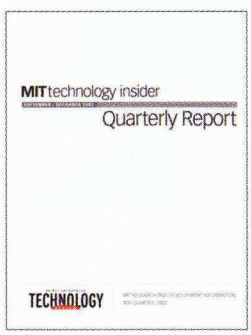

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WHY I.T. MATTERS

The trendy notion that information technology has lost its power to confer business advantages is dead wrong, says a leading technologist and venture capitalist.

BY ROBERT M. METCALFE ILLUSTRATION BY DAVID PLUNKERT

A **YEAR AGO,** *Harvard Business Review* published a now infamous article called "IT Doesn't Matter." Its author, the magazine's then executive editor Nicholas G. Carr, argued that information technology no longer gives businesses a competitive edge. Carr called information technology managers impatient, wasteful, passive, and lured by the chorus of hype about the so-called strategic value of IT. *Harvard Business Review* has 243,000 extremely influential readers. So if it publishes an article saying that information technology doesn't matter, then an awful lot of important business leaders are going to believe it. And if they do, they'll run their companies—and our economy—into a ditch.

Many commentators have debunked Carr's article since it appeared last year. So many in fact that I feel like Elizabeth Taylor's ninth husband: I know what to do, but how to make it interesting? But Carr's article just won't stay debunked. And now he has expanded his thesis into a new book called *Does IT Matter?*, which the Harvard Business School Press published in April. The question-style title hints at some backpedaling, but Carr's point is basically unchanged—and it needs debunking yet again.

Since I do not subscribe to the ink-on-dead-trees version of the magazine, I bought my copy of Carr's May 2003 paper through Amazon.com. It was delivered over the Internet in minutes as a PDF file for $7.00. Carr's new book is also listed on Amazon.com, a triumph of IT-enabled corporate strategy. We see that IT apparently matters to Harvard.

Carr himself has a website, nicholasgcarr.com. IT apparently matters to Carr.

Let's face it: IT matters to everyone.

TWO TRILLION REASONS THAT I.T. MATTERS

I asked how much IT matters of Frank Gens, senior vice president for the information technology market research giant IDC. (Full disclosure: IDC is owned by IDG, on whose board I serve.) IDC reports that the global investment in information technology (including telecommunications) totaled $1.9 trillion in 2003 and, despite Carr, will climb to $2.0 trillion in 2004.

According to a 2003 IDC survey, non-IT business executives spend 20 percent of their time thinking about IT. Are they wasting their time? Again despite Carr, almost 60 percent say that the strategic importance of IT is increasing; only 2 percent say the importance is decreasing. Carr may claim these Harvard-MBA-type executives are foolish or misguided, but 55 percent feel that their companies should use information technology more aggressively; 43 percent feel their usage is just right; and only 2 percent feel that they should be less aggressive.

In Carr's world, information technology managers are apparently fools, or even frauds, to the tune of $2 trillion per year. Presumably, these managers slavishly upgrade to whatever new thing vendors want to sell. But in the real world, millions of people already work hard to spend their IT budgets wisely. The computer-trade press has been covering this complicated process for almost 40 years.

In warding off his debunkers, Carr has offered some clarifications of his argument. He doesn't really mean that information technology doesn't matter; rather, he says, his point is that because IT has been commoditized, like electricity, it confers upon its business users no competitive advantage. He also clarifies that he does not mean that information itself doesn't matter, nor does he mean that the people using the technology don't matter. What really doesn't matter, he says, is the no-longer-proprietary technology infrastructure for storing, processing, and transmitting information. So we can only hope that most of *Harvard Business Review*'s captains of industry read beyond the article titles before dropping the magazine on their coffee tables.

Carr concludes that since information technology no longer provides a competitive advantage to businesses, they should stop spending wildly on advanced information technology products and services. He admonishes managers to stop being suckers for the latest cool products from Cisco, Intel, Microsoft, Oracle, et al. IT managers should stop squandering corporate assets and begin acting in the best interests of their shareholders. They should become boring minimizers of IT cost and risk.

As evidence, Carr points out that my 30-year-old baby, Ethernet, has been standardized and commoditized. It's true that last year more than 184 million new Ethernet ports were shipped, at a value of $12.5 billion, and that anyone can buy them. Most of those ports are the current mainstream version of Ethernet, which carries data over wires on local-area networks at 10 or 100 megabits per second.

IF BUSINESS LEADERS

But now that the post-Internet-bubble nuclear winter is almost over, Ethernet is speeding up, to beyond 1,000 megabits (one gigabit) per second. Ethernet is going into wide-area networks. It's going wireless. It's going into embedded systems—the eight billion microprocessors shipped every year that don't go into PCs.

New Ethernet standards are being created, new commoditization races are being started, and Ethernet, if ever it wasn't, is once again a tool of corporate strategy. In the article and now again in his book, Carr wrongly equates today's information technologies with electricity, and then he wrongly characterizes electricity as static. In short, Carr, deep into a post-bubble depression, wrongly declares the end of history.

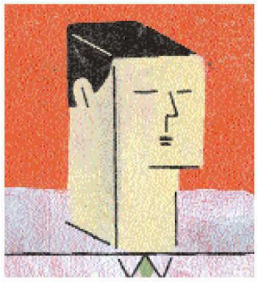
The history of electricity is not over, however. Controlling electrical power grids is still famously problematic, and that's to say nothing of the exciting developments in technologies such as wind, solar, fission, fusion, hydrogen, and batteries, all of which present strategic opportunities. And information technology is bigger and more recent than electricity. Both are still rapidly evolving; both are very much alive as important elements of corporate strategy.

Much of the research on information technology usage that Carr cites is of dubious validity. Take, for example, the studies that, as Carr puts it, "consistently show" that expenditure on IT as a fraction of company revenue is inversely correlated with financial performance. One study that Carr cites states that the 25 companies with the highest economic returns spent on average just .8 percent of revenues on IT, while the typical company spent 3.7 percent. But this hardly proves Carr's conclusion. Rather, it

indicates that companies investing wisely in IT increase revenues much faster than those that invest unwisely, too little, or not at all. Companies that invest poorly in IT don't increase revenues as quickly, so their IT expenditures are higher as a fraction of revenue. Companies that invest unwisely in IT go out of business and are not counted in the studies. IT still matters.

RAINING ON THE I.T.-BASHERS' PARADE

Carr is not the first person to question the value of information technology. Paul Strassman, for example, despite being a high-profile, big-budget chief information officer for such organizations as NASA, the U.S. Department of Defense, and Xerox, has made a second career of studies not finding the benefits of IT. Morgan Stanley economist Stephen Roach is another famous critic of IT. During the 1990s, he claimed that increasing investments in information technology were showing no benefits. Roach, echoing MIT economist Robert Solow, wrote that IT investments were not appearing in U.S. productivity numbers. I called Solow, a Nobel Prize winner, and he admitted that this so-called productivity paradox might easily be explained by how poorly productivity is measured. Productivity numbers are hard to come by, and Roach relied on outmoded methods. But Roach stuck by his IT-doesn't-matter numbers, like the proverbial drunk looking for his wallet under a street lamp.



BELIEVE THAT I.T. DOESN'T MATTER, THEY'LL RUN THEIR COMPANIES—AND OUR ECONOMY—INTO A DITCH.

Today, information technology accounts for about half of capital expenditures by U.S. companies. Productivity is high and increasing rapidly. What is Roach saying now? He says that the productivity numbers are highly questionable. In other words, if the data conflict with your theory, throw out the data. It makes me wonder whether Roach, like Carr, just has a bad attitude about IT.

In Carr's reply to early critics, published on the Web by the *Harvard Business Review* in June 2003, he wrote that his article "has at least succeeded in setting off an important and long-overdue debate about the role of information technology in business." I don't think so. If anything, Carr has succeeded only in misleading his readers.

Howard Smith and Peter Fingar, in their 2003 book *IT Doesn't Matter—Business Processes Do*, argue that Carr is not only wrong but dangerous. They remind us of what happened when *Harvard Business Review* published Michael Hammer's 1990 article "Reengineering Work." Too many Harvard MBAs decided to take the easy part of Hammer's advice and downsized their companies to death. Unless Carr's argument is debunked, the current crop of reigning MBAs will be tempted to run WordPerfect on mid-1980s PCs connected to IBM 360 mainframes.

Which brings us to Carr's central conceit. He urges IT managers not to venture foolishly out onto technology's cutting edge and to buy only that which has low risk and high value to their companies. Carr urges this as if it were breaking news.

In fact, IDG alone publishes 300 information technology magazines worldwide, and each has several competitors. All of these have been offering advice for decades on just how far onto the bleeding edge of technology it is wise to go to give your company an edge. Taking technology risks, when done well, can bring competitive advantage. When done poorly, it can bring disaster. But that's a balancing act that the information technology managers of the world were well aware of long before Carr put in his two cents.

We often brag about the marvelous U.S. innovation machine. We brag about our world-leading research universities. We brag about our entrepreneurs and the venture capitalists, like me, who back them. But there is an unsung player in our marvelous innovation machine: the aggressive users of information technology. In Germany, by contrast, it's hard to buy IT unless it's from Siemens. In the United States, startups readily find managers out on the cutting edge, searching for new, smarter, and more efficient ways to do things—a quest that keeps our vaunted innovation machine humming.

If business executives follow Carr's advice, who will provide innovation's test beds? How will new technologies find their markets? This may be the most important reason to debunk Carr's arguments once and for all: if they harden into conventional business wisdom, American ingenuity will be strangled in its bassinet.

I serve on the board of a small public company in Silicon Valley called Avistar. For 10 years, Avistar has been marketing networked desktop videoconferencing to large companies. Avistar's hardware and software have worked increasingly well for a long time. What's taking time is their adoption—the search for one situation after another in which the technologies provide a value that's worth the risk.

Avistar CEO Jerry Burnett disagrees strongly with Carr and recommends a division of labor in IT management. On one hand are specialists in what Burnett calls "availability management." These might be mistaken for the cost and risk minimizers that Carr extols. On the other hand are specialists in "adoption management." These are the people Carr wants demotivated, demoted, or fired.

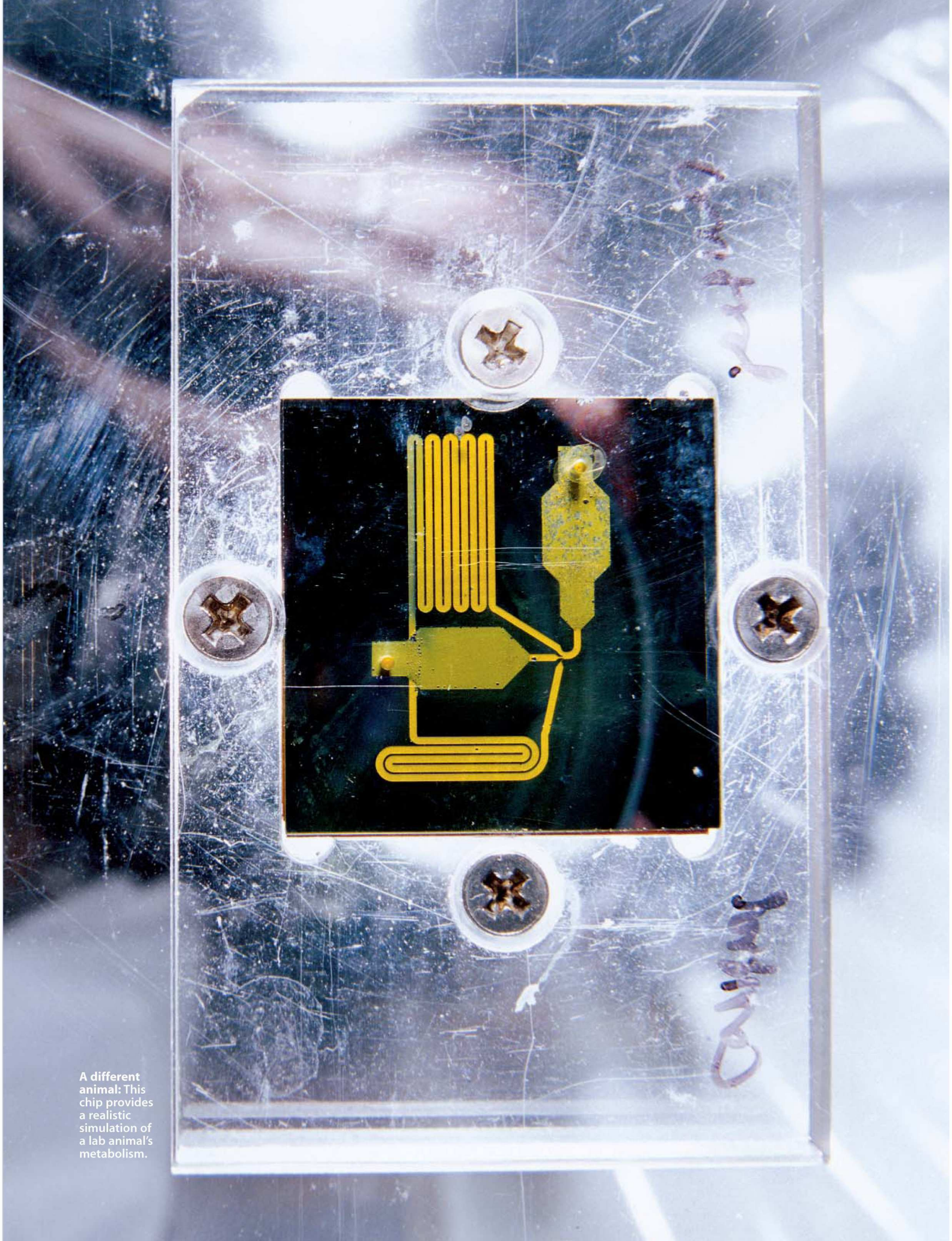
Carr argues that things that are widely available, like IT, cannot be used for sustained competitive advantage. Well, since *Harvard Business Review* is received by almost a quarter-million people and can be bought by anyone with $16.95, then according to Carr's own argument, that publication itself doesn't matter. Cancel your subscription and download any interesting articles from back issues—which any teenager will be able to find for you on the Internet for free.

Robert M. Metcalfe, a venture capitalist at Polaris Venture Partners in Waltham, MA, is the inventor of Ethernet and founder of 3Com. He is also a member of the *Technology Review* board. This article is adapted from a debate he had with Nicholas Carr in March at a gathering of 500 IT managers organized by *Computerworld* magazine.

the silicon guinea pig

Pharmaceutical companies anxious to see if experimental drugs have toxic side effects may soon turn to a thumbnail-sized silicon chip, packed with live cells, that mimics the metabolism of a lab animal. Such "animal on a chip" devices could help to quickly and cheaply spot toxic compounds, sparing companies years and millions of dollars in the drug discovery process.

BY DAVID H. FREEDMAN | PHOTOGRAPHS BY DAVID BARRY



A different animal: This chip provides a realistic simulation of a lab animal's metabolism.

AT FIRST GLANCE, Michael Shuler's chip could pass for any small silicon slab pried out of a computer or cell phone. Which makes it seem all the more out of place on a bench top in the Cornell University researcher's lab, surrounded by petri dishes, beakers, and other bio-clutter and mounted in a plastic tray like a dissected mouse. The chip appears to be on some sort of life support, with pinkish fluid pumping into it through tubes. Shuler methodically points out the components of the chip with a pencil: here's the liver, the lungs are over here, this is fat. He then injects an experimental drug into the imitation blood coursing through these "organs" and "tissues"—actually tiny mazes of twisting pipes and chambers lined with living cells. The compound will react with other chemicals, accumulate in some of the organs, and pass quickly through others. After several hours, Shuler and his team will be closer to answering a key question: is the compound, when given to an actual human, likely to do more harm than good?

This so-called animal on a chip was designed to help overcome an enormous obstacle to discovering new drugs: there is currently no quick, reliable way to predict if an experimental compound will have toxic side effects—if it will make people sick instead of making them well. Testing in animals is the best drugmakers can do, but it is slow, expensive, often inaccurate, and objectionable to many. To minimize the number of animal tests, drug companies routinely screen drug candidates using cell cultures—essentially clumps of living human or animal cells growing in petri dishes or test tubes. The approach is relatively cheap and easy, but it gives only a hazy prediction of what will happen to a compound on the circuitous trip through the tissues and organs of an animal.

Shuler is among a handful of researchers who are developing more sophisticated cell cultures that simulate the body's complex organs and tissues. MIT tissue engineer Linda Griffith, for one, has built a chip that mimics some of the functions of a liver, while Shuichi Takayama, a biomedical engineer at the University of Michigan, has built one that imitates the behavior of the vasculatory system *(see "Other Animal-on-a-Chip Efforts," p. 67)*. But while such efforts have produced convincing analogues of parts of human or animal bodies, Shuler has gone a step further. Working with colleague Greg Baxter, who launched Beverly Hills, CA-based Hurel to commercialize the technology, Shuler has combined replicas of multiple animal organs on a single chip, creating a rough stand-in for an entire mammal. Other versions of Shuler's chips attempt to go even further, using human cells to more faithfully reproduce the effects of a compound in the body.

Drug companies are interested, and no wonder: they routinely make thousands, even tens of thousands, of compounds in hopes of finding one that is effective against a particular target. Chips such as Shuler and Baxter's could mean a cheap, fast, and accurate way to weed out compounds that would eventually prove toxic, saving companies years and millions of dollars on the development of worthless drugs. According to a recent study by Tufts University's Center for the Study of Drug Development, for each drug that reaches market, the drug industry spends an average of $467 million on human testing—the vast majority of the money going to drugs that fail, either because they aren't effective or because they prove toxic. If more failures could be identified before animal testing even began, companies could focus more of their time and money on the winners. "Everyone in the industry hopes to have surrogates for animals and humans when it comes to testing compounds," says Jack Reynolds, head of safety sciences for Pfizer, the world's largest pharmaceutical firm. "This is the sort of technology we'd want in our toolbox."

POISON PILLS

The toolboxes of drug developers are already stocked with a host of simple cell-culture tests aimed at quickly predicting which would-be drugs will have toxic side effects. The problem with these tests is that they're often *too* simple. A typical scenario: researchers squirt a solution containing an experimental medication into petri dishes where live cells harvested from a rat's lungs float in a nutrient-rich broth. If the cells die, the researchers table the compound and try another; if the cells survive, they begin the lengthy and expensive process of testing the compound on mice, rats, and other animals. But the compound's failure to kill the lung cells offers little insurance that it won't make people sick.

When a person takes a drug, its active ingredient goes on a wild ride to get to the target cells: it might be absorbed by the gut, broken down by enzymes in the liver, hoarded for weeks by fat cells, screened out by a brain membrane, and whirled through the whole ordeal over and over again by the blood. When that happens, an otherwise harmless compound can accumulate in a particular organ until it reaches toxic levels. Or it can be transformed into a different compound altogether, which itself is toxic. Pfizer's Reynolds estimates that, of drug candidates that end up proving unsafe, approximately 40 percent acquire their toxicity after being converted to other compounds in the body.

Drug developers have no quick, reliable way to **predict if an experimental compound will have toxic side effects**—if it will make people sick instead of making them well.

One reason that conventional cell-culture tests often mislead researchers is that they don't present the complex brew of enzymes and other chemicals that a drug can encounter and react with in the various tissues of the body. And simple cell cultures don't reveal how much of a drug actually gets to different types of cells, in what form, and for how long. Indeed, nearly half of the drugs that seem safe in cell-culture testing prove toxic in animal tests; and even more fail when they encounter the complex tissues and organs of humans. Researchers hope, however, that cell cultures that better simulate the conditions in the body will do a far better job at spotting toxic drugs, reducing the reliance on animal and human testing. "The holy grail of the industry is to be able to predict toxicity from a cell culture," says Peter Lord, head of mechanistic toxicology in preclinical development at Johnson and Johnson Pharmaceutical Research and Development.

A cultured approach: Cornell University's Michael Shuler takes cell cultures to a new level.

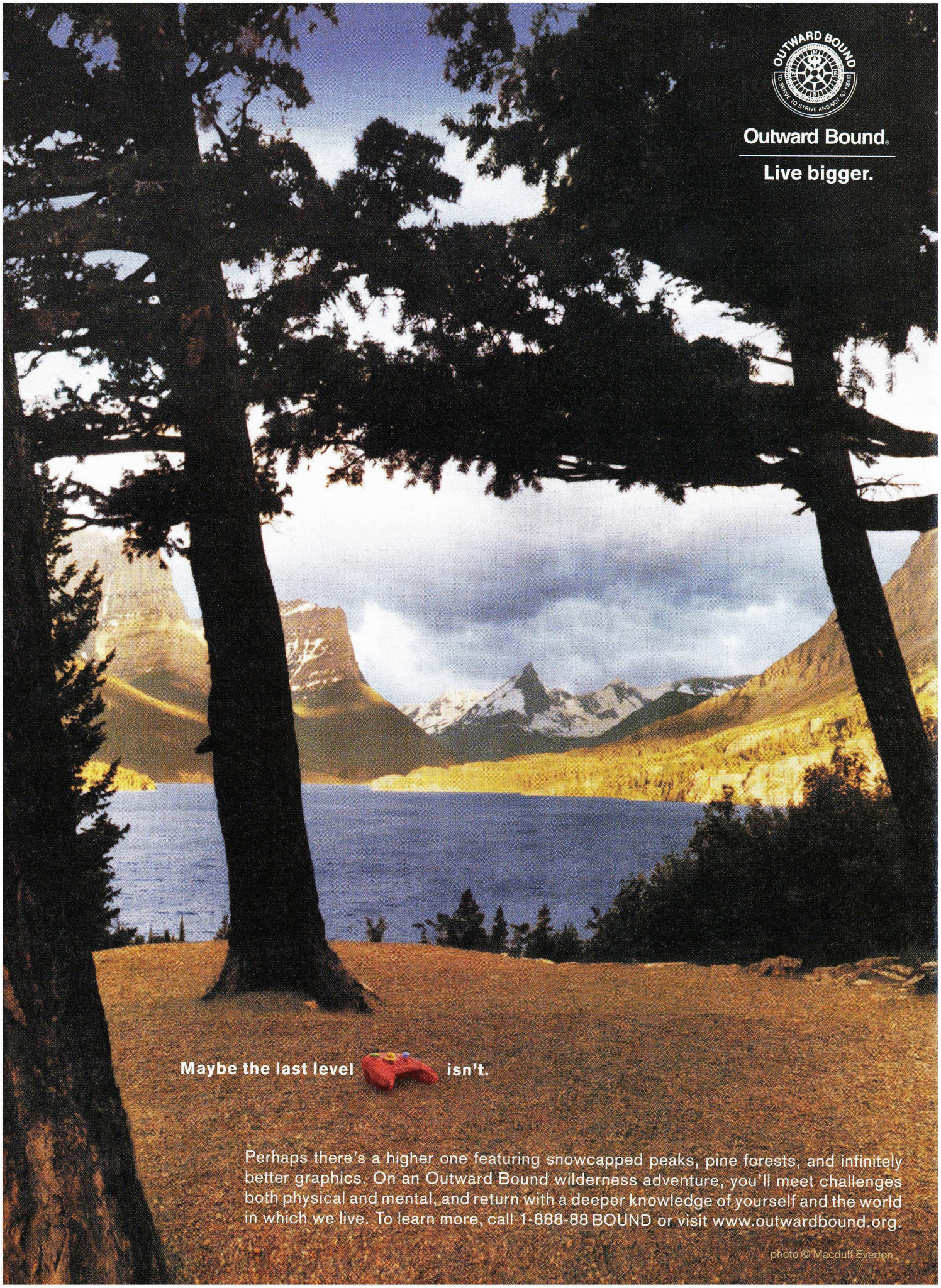

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photo © Macduff Everton

TINY PLUMBING

Michael Shuler is a 57-year-old, lanky chemical engineering professor who has nurtured a side interest in biological processes since junior high school. By 1989 he had become interested in toxicity testing, and he had been pondering the unreliability of conventional cell cultures when an idea occurred to him: could you make a cell culture that replicates the journey through the various organs? He recognized it as a chemical engineering problem: glass chambers lined with different types of cells and hooked up via tubes to each other and to a pump that sent fluid through them would far more realistically simulate a body, and tests employing them might predict what happens in living animals much more accurately.

After several months, Shuler and students had constructed a bench-top conglomeration of cells and plumbing providing a crude working model of a set of mammalian organs. It sort of functioned, but Shuler knew there was a big problem with its fidelity: almost all of the chemistry in the body takes place in tissues packed with minute canals and chambers, where critical reactions hinge on the ability of various chemicals to concentrate in some places and diffuse in others, depending in part on the microscopic geography. Mixing everything up in big beakers would distort that delicate balance. Plus, at this size the system wouldn't be practical or cheap enough for large-scale testing.

Meanwhile, molecular biologist Greg Baxter had just joined Cornell's Nanobiotechnology Center as a research scientist. His specialty was microfluidics—essentially, microscopic plumbing on a chip. On his second day he buttonholed Shuler at his lab, wondering if he had any projects that could benefit from ultraminiaturization. Funny you should ask, said Shuler.

It took just two meetings to hammer out the basic chip design and a year to produce the first prototype. To build one of the devices, the researchers carve minute trenches that look like faint scratches into a thumbnail-sized silicon chip; these trenches serve as fluid-carrying pipes. Producing microfluidic features on chips for testing chemical reactions and imitating biological processes is not new. But by combining their skills in chemical engineering and microfabrication, Shuler and Baxter add a significant twist: they've engineered the sizes, lengths, and layout of all the trenches in an attempt to closely duplicate the fluid flows and chemical exposures that cells experience in real organs.

The trenches act as surrogate blood vessels, carrying chemicals within and between the chip's ersatz organs, which are themselves composed of trenches that are tightly spiraled or snaked into dense clots roughly half a centimeter wide. Thousands of living cells are fixed to the floor of each organ's trenches. A brick-sized external pump circulates a nutrient-rich fluid—a stand-in for blood—through the chip. When a test compound is added to the fluid, its silicon journey is roughly analogous to what it would undergo in a live mammal, thanks to 13 years of fiddling with each organ's size, pattern, and interconnects, and with the sizes and shapes of the various trenches. "We wanted the cells' environment to be as realistic as possible, from the delivery of nutrients and the removal of waste products to the mechanical stresses that it experiences," says Shuler.

No one knows how many drugs that would have been safe in humans were shelved because they sickened some animals.

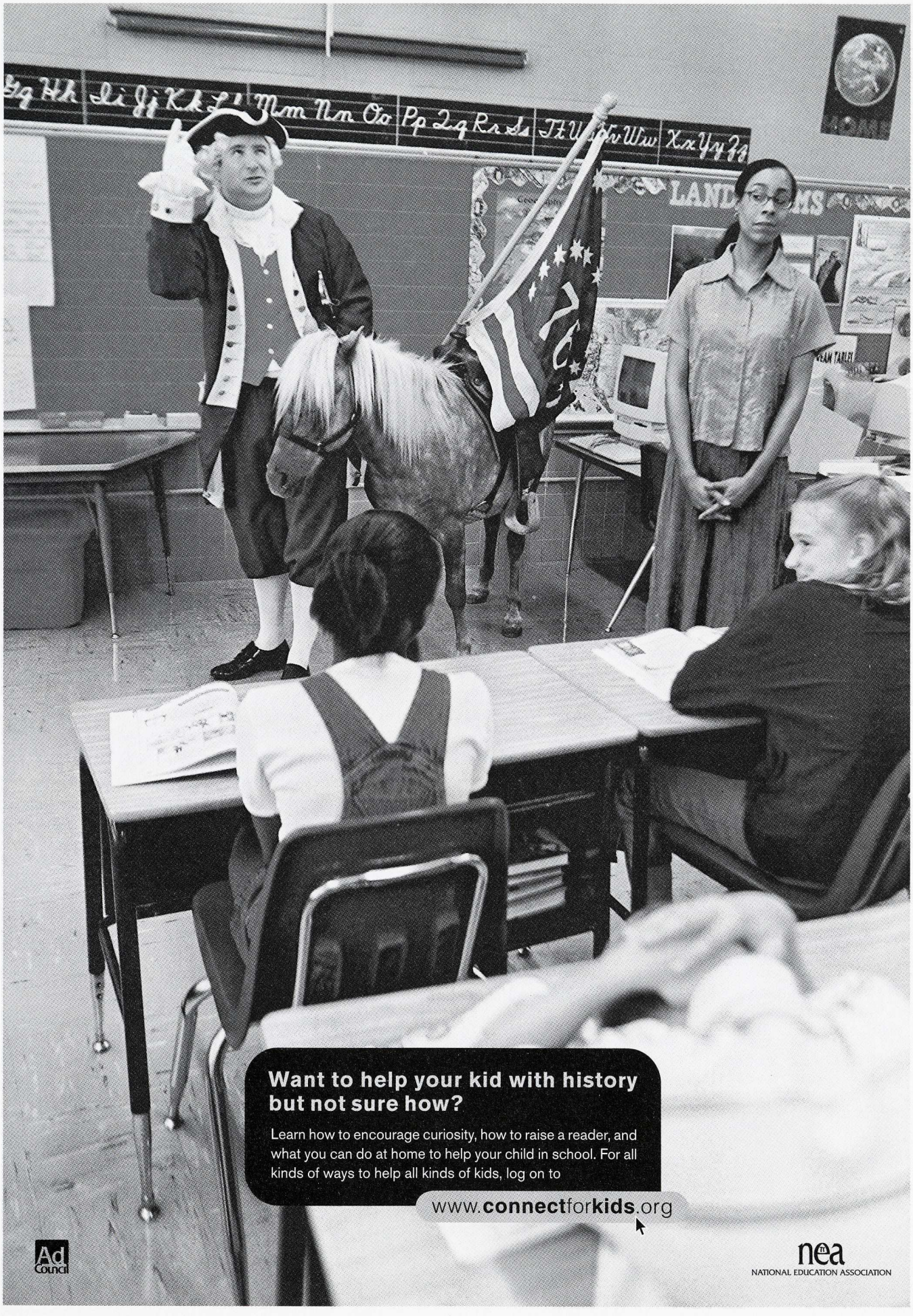
After a test compound has circulated through the chip for several hours, the cells in the chip are monitored, either with a microscope or via embedded sensors that can test for oxygen and other indicators. Do the cells absorb the compound? Does it sicken or kill them? As in an actual animal, each organ or tissue plays a specific role in the chip. The liver and gut break some compounds down into smaller molecules, for example, while the fat—jammed not only with cells, but also with a spongelike gel—often retains compounds, allowing them to leak out later. A "target" organ or tissue is usually included to demonstrate the ultimate effects of the compound; this might be a cancer tumor, or an especially vulnerable tissue, such as the lung's, or bone marrow.

The chips, of course, will have to be extensively tested before drug firms will use them widely. Still, early signs are encouraging. Shuler ran one experiment with naphthalene, a compound used in mothballs and pesticides. Excessive exposure causes lung damage, but you wouldn't know it from standard cell-culture tests. That's because the culprit isn't naphthalene itself but rather two chemicals produced by the liver when it breaks naphthalene down. If you knew that and splashed those by-products directly on lung cells in culture, you'd observe such a severe response that you'd conclude even slight exposure to naphthalene is extremely dangerous. But that's wrong, too; as it turns out, fat cells yank much of the toxic compounds out of the system. Shuler's chip convincingly mimics this chain of events, yielding a realistic measure of the damage.

Such precise simulation promises to help drug companies improve their screening of drug candidates—and waste less time and money on those that will ultimately fail animal tests. According to Baxter, the chips are ready for such an application right now, and six large companies are currently talking to Hurel about adopting the technology. Shuler, aided by a team of students and collaborators at Cornell and elsewhere, is working on further shrinking and automating the technology. The goal: a sheet-of-paper-sized bank of 96 chips that plugs into a robotic lab setup that very rapidly adds test drugs and monitors the results. The system could not only replace conventional cell cultures but also reduce a reliance on animal experiments, in which researchers must use a great number of animals to test dif-

OTHER ANIMAL-ON-A-CHIP EFFORTS

PROJECT LEADER	GROUP	TECHNOLOGY
Dawn Applegate	RegeneMed (San Diego, CA)	Chips lined with human liver tissue for drug screening
Linda Griffith	MIT (Cambridge, MA)	Liver on a chip for drug screening
Paul Kosnik	Tissue Genesis (Honolulu, HI)	Chips with vascular and ligament cells for developing tissue replacement
Shuichi Takayama	University of Michigan (Ann Arbor, MI)	Cell-culture chips with channels that mimic the vasculatory system
William Wang	Pharmacom (Iowa City, IA)	Drug-screening chips that will include cells from the brain and other organs


Want to help your kid with history but not sure how?
Learn how to encourage curiosity, how to raise a reader, and what you can do at home to help your child in school. For all kinds of ways to help all kinds of kids, log on to
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Ad Council
nea
NATIONAL EDUCATION ASSOCIATION

Silicon life support: A brick-sized pump sends a nutrient-rich fluid through an "animal on a chip" (bottom right).

ferent doses of a drug, and must monitor those animals over time to pick up subtle side effects. "We're talking about running a test in one or two days that would take months with animals," says Shuler. Shuler projects a per-chip production price of about $50 complete with cells, compared to the hundreds or even thousands of dollars it takes to acquire and maintain a single lab animal.

KIND OF HUMAN

Chips that replicate the functioning of animals will likely be the first versions of the technology to make a commercial impact. But the hope is that once those prove to accurately predict the results of animal tests, human-on-a-chip versions will provide a good indication of how toxic a drug is likely to prove in human trials.

Animal testing plays that role now, but not very well. Four out of five drugs that make it through animal testing end up failing in human clinical trials, usually because of safety concerns. Part of the problem is that mice can't tell you they have headaches, blurred vision, or stomach cramps. But the larger issue is simply that animals' organs, and the processes that take place in them, are not identical to those of humans. No one knows how many drugs that would have been safe in humans were shelved because they sickened some animals. (Penicillin, for instance, is toxic to guinea pigs but fortunately was also tested on mice.)

Chips containing simulated human tissues and organs could also allow researchers to work out complicated multidrug schemes for treating various diseases without putting patients through agonizing rounds of trial and error. Shuler, for instance, is zeroing in on anticancer cocktails. He incorporates human cells from uterine or colon tumors in his chips, setting up a more realistic model of a particular type of cancer. He can then test the ability of various combinations of chemotherapy drugs to kill the cells without sickening the rest of the system. "To find good combination therapies, you need to run a lot of tests to determine the right doses and the order in which the drugs are given," he explains. "It's the sort of problem we can get our hands around with this technology."

Neither Baxter nor Shuler claims that the animal on a chip is any sort of panacea for the complex and deeply challenging drug-development process. For one thing, the chips still have to prove in large-scale tests that they really do a better job than conventional cell cultures of predicting toxicity. But if they measure up, then the pills you take ten years from now may very well arrive thanks to the sacrifices of a silicon lab rat.

David H. Freedman is a freelance journalist based in the Boston area and the author of five books. His last story for *Technology Review* was "The Virtual Heart" (March 2004).

DEMO

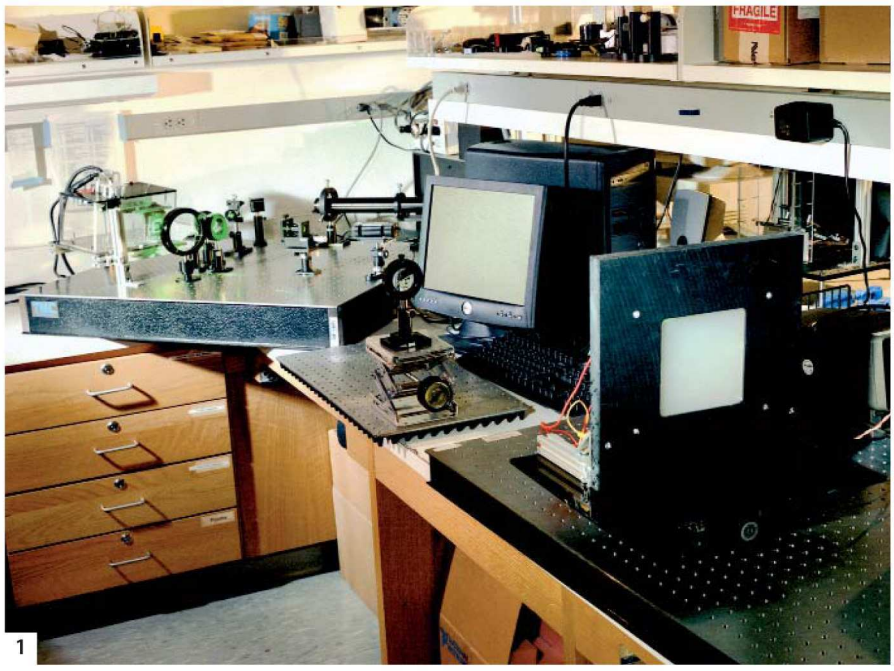
Holographic TV

Ready for *Survivor* 3-D? Harold Garner is creating technology that could make holographic TV—and a long list of other holo-devices—a reality.

PHOTOGRAPHS BY CHARLES FORD

MORE THAN A QUARTER OF A CENTURY AGO, George Lucas teased movie audiences with a holographic message from a princess in distress. Today, tucked away in a second-floor warren of the University of Texas Southwestern Medical School at Dallas, physicist Harold Garner and a team of engineers are building the technology that may finally bring moving 3-D images into the living room. Asked whether his HoloTV project will make images like Princess Leia's plea for help possible, he laughs and says, "We already know what our very first real movie is going to be": a re-creation of Leia's appeal. Garner hopes this planned video will be "the first holographic talkie." His lab is an engineer's haven—and a bit out of place in a medical school. But technologies created by his team are crucial to modern biomedical research and will be to future medical practice. While holographic television may seem far afield even of that mission, medical imaging, such as sonography, is near the top of a seemingly infinite list of applications for dynamic holograms. "Heads-up" displays for pilots and soldiers, 3-D video games, and air traffic control screens are a few of the other near-term uses Garner sees. And while holographic TV may take another decade of development, Garner had no doubts its day would come as he showed *TR* contributing editor Erika Jonietz how the system works.

1. THE BIG PICTURE. Garner leads the way into a small, crowded room. The holographic projection system occupies most of two countertops. "We think it's going to be very robust, and it's going to be inexpensive, because you take a Pentium, a part of a light projector, and a laser, and you've got it," he says. The two-gigahertz computer at the system's center holds digital maps of holograms, created either from images from a special camera or from computer models. The computer uses the maps to drive a "digital micromirror device," a postage-stamp-sized chip taken from a digital computer projector. Green laser light from a long, black tube mounted to the left of the computer bounces off the chip. It then passes through round, focusing lenses and shines on a special multilayer screen at the far right, which looks a bit like a primitive computer monitor.



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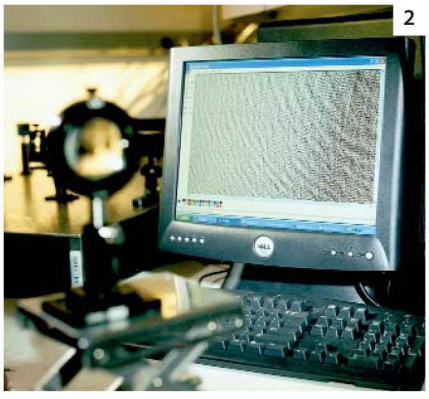
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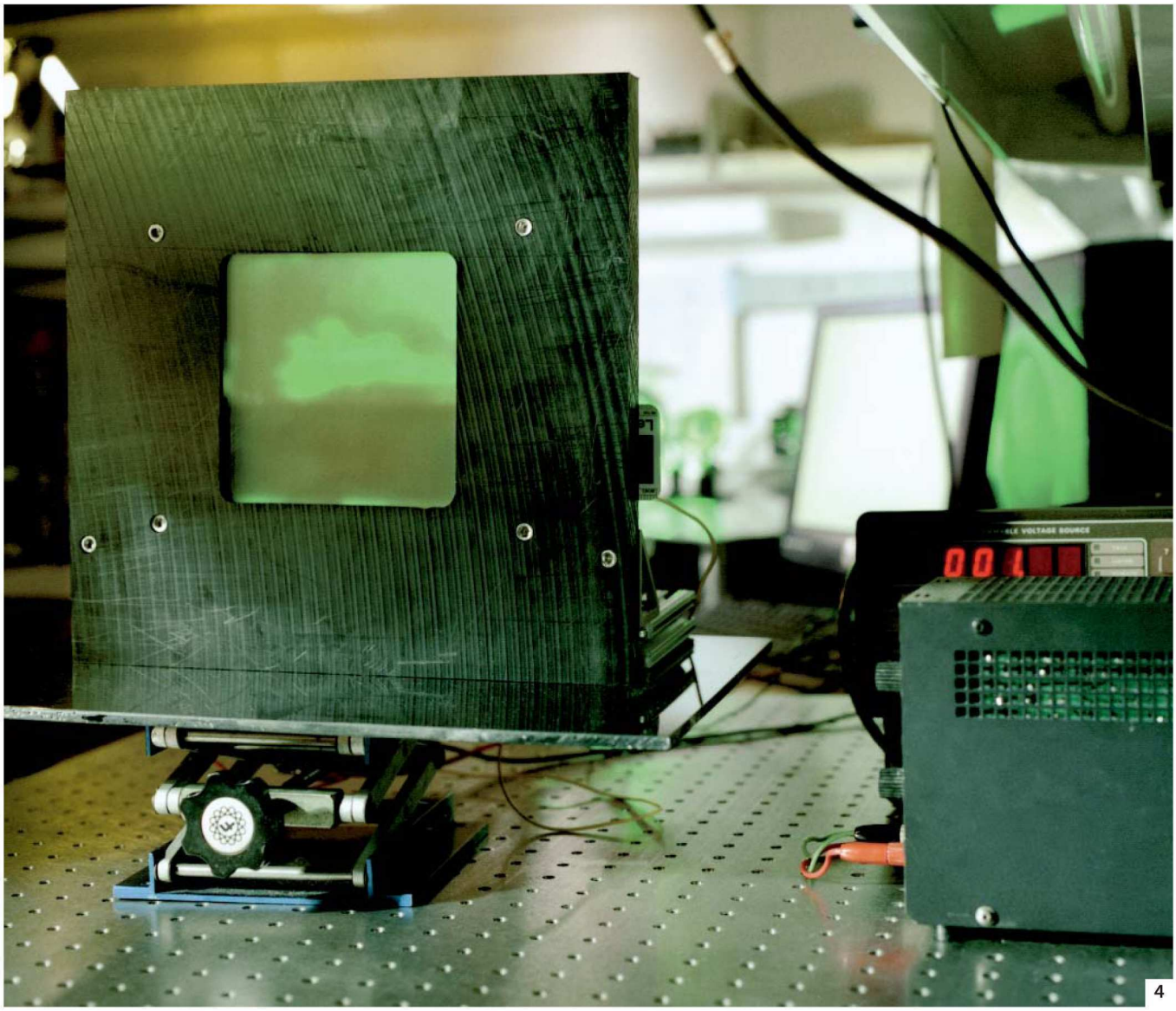
2. PICTURE THIS. Usually with a digital projector, the image on the computer screen shows up on the wall. But, Garner warns, that's not the case here. Raj Munjuluri, the project programmer, pulls up a sample hologram on-screen. It looks like a magnified fingerprint, not a 3-D object. "In the computer," Garner explains, "we create a three-dimensional volume that can contain multiple objects—airplanes moving around one another, whatever. We calculate an 'interferogram' from that, that is, a two-dimensional image that contains all the three-dimensional data." That is the image on the computer screen. At the tap of a button, the interferogram begins to flicker. Munjuluri's hologram is not a still image; it's actually a near-video-speed movie of a helicopter circling a jet.


3

3. THE HEART OF THE MATTER. Munjuluri reaches in to adjust a lens to the right of the micromirror device. This chip, made by Texas Instruments, has 800,000 tiny mir-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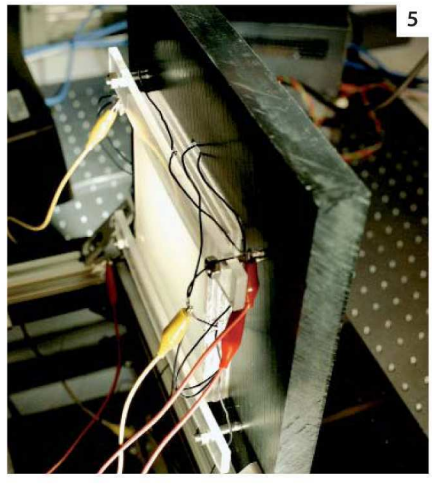
rors, each only 16 micrometers square and perfectly flat. The computer tilts the mirrors to create the image on the screen, as in any digital projector. "Each mirror is a pixel," says Garner. But in a standard projector, the mirrors reflect red, green, and blue light to produce a 2-D image. Illuminated with laser light, these mirrors instead flip to reconstruct an interference pattern that contains 3-D data, explains Michael Huebschman, a physicist in the group. And full-color pictures will supplant today's ghostly green images with the addition of red and blue lasers, each reflected by a different chip in order to boost resolution, he says.

4-5. SEEING 3-D. Garner shows off the end result: a slightly fuzzy but definitely 3-D fighter jet soaring through a special screen, developed to allow true 3-D viewing. The current version consists of eight layers of liquid-crystal films adapted from commercial applications. The films are normally milky white, but when supplied with a voltage, they turn clear (5). As each layer is turned off and on in rapid sequence, a different slice of the image becomes visible against the white background. Sequenced quickly enough, the plates show a steady, volumetric image of the airplane. Soon, Garner says, the display device will be expanded to 32 plates turning on and off at one-millisecond intervals, allowing video with greater depth and less flicker. Garner hopes to have a prototype that fits the entire system into a portable box this summer. His first target application is heads-up displays for the military, systems that project battlefield information on a pilot's windscreen or a soldier's helmet without obstructing the view. Future plans include scientific and engineering displays, then medical imaging, and eventually entertainment. "I personally want a Game Boy," Garner says, grinning. Within 10 years, he adds, holographic TV could be a reality. What are the odds it will really happen? Good, he says. "I gotta have something to retire on!"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Cargo Security

BY CORIE LOK | Photograph by David Nicolas

TECHNOLOGY REVIEW: How vulnerable is the cargo shipping system to attack?
STEPHEN FLYNN: The system was designed with virtually no security built into it. Is there an opportunity to put a weapon of mass destruction into the system? Yes. Anybody on the planet who has between $3,000 and $5,000 can get a 40-foot [12-meter] box dropped off at their home or backed up to their workplace. They can load it with up to 32 tons [29 metric tons] of material, close the doors, put a 50-cent lead seal on it, and it'll be off to the races.

TR: There's no inspection of the containers?
FLYNN: The Bureau of Customs and Border Protection only inspects those containers it has determined to be "high risk." The figure that's in use today is that 4 percent of all containers are somehow physically inspected. There aren't really firm standards set for inspection. It could be the inspectors simply looked at the documentation. It could mean that they looked at the seal to see that the seal hadn't been tampered with, or they looked at the exterior of the box to check that the thing hadn't been breached. It could mean that they physically opened the back door, and everything looked fine in the dark, and they closed it back up. It could mean that they ran a nonintrusive scanner to x-ray the interior. Or it could mean that they opened up the box and took everything out and looked it over. Since a container can hold up to 32 tons of material, unladening or "unstuffing" the box is very rare.

TR: That doesn't sound very secure.
FLYNN: It shouldn't. But the real question here is, how can we be confident the other 96 percent are low risk? The targeting system used by U.S. government agencies to trigger an inspection relies heavily on the cargo manifest. The manifest is supplied by the transportation provider, such as a shipping company, but it's essentially secondhand information. The manifest says, "This is what my customer tells me that I'm shipping, and I'm going to take his word for it." The transportation provider doesn't do any verification of its own.

TR: What would happen if terrorists did blow up a container?
FLYNN: If you had even one container go off, or if it's al-Qaeda-style, you have three, then it immediately will raise the question in America's mind: if this one box could go off, which was presumed to be legitimate, what about all the other boxes? And the answer right now would be we really don't know. So the political imperative will be that you will shut the system down until you can sort it out.

Within about three weeks, you'll shut down the global trade system, because you've got 90 percent of general merchandise, virtually everything that goes into retailing, everything that goes into the manufacturing sector, moving in these ubiquitous 40-by-8-foot [12-by-2.4-meter] boxes. And it doesn't have to be a weapon of mass destruction. It can be just a reasonably high-end conventional explosive, like a major truck bomb.

TR: What effect would shutting down the system have?
FLYNN: It means global recession. Probably global depression. The person on the street may think, "I'll just go to Wal-Mart and get what I need." Well, Wal-Mart, within two weeks, will have nothing on the shelves. Because there are no warehouses: their warehouse is in the transportation and distribution system. So it's a tremendous vulnerability that has cascading effects, not just for the bottom line, but for the daily lives of Americans. A good example is the West Coast longshoremen lockout of the fall of 2002. It's estimated this 10-day event cost the U.S. economy over $20 billion.

STEPHEN FLYNN

POSITION: Jeane J. Kirkpatrick Senior Fellow for National Security Studies, Council on Foreign Relations

ISSUE: Container security. The cargo shipping system moves tens of millions of containers around the world each year by train, truck, and ship, with next to no security. What can technology do to make the system less vulnerable to terrorist attacks?

PERSONAL POINT OF IMPACT: Using security expertise garnered as a U.S. Coast Guard commander, helped initiate Operation Safe Commerce, a $58 million federal pilot project to test container security technologies at the Port of New York and New Jersey, the Ports of Los Angeles and Long Beach, and the Ports of Seattle and Tacoma

TR: Are there technologies out there that could improve security?
FLYNN: The good news is that there are, and they're off the shelf, or near off the shelf. One key thing is the need to track the containers that move through the system. The technology for this is a combination of Global Positioning System and radio frequency identification [RFID] technologies. We don't need to have real-time data about where every box is. We need to capture a record of where the boxes have been, and then at key points we interrogate the box to find out, "Where have you been, what have you been up to?" That can get downloaded through RFID. Then that information gets relayed to somebody who decides, "Oh, there's information here that arouses my concern. Before this box is allowed into this loading port, I want it set aside so we can check on it. All the other boxes can keep going." But there may be some places where, because there's particularly high risk of other things happening, such as cargo theft, you want real-time GPS tracking.

TR: What about checking to make sure the boxes haven't been tampered with?
FLYNN: The kinds of things we're looking at are sensors built into the box that can pick up things like light, or change in barometric pressure, or change in temperature, which would only come from somebody breaching the wall of the container or opening the door. And then there are other sensors out there for dealing with very important issues like radiation. All these sensors are important, because you can literally punch your way through the boxes. It takes next to nothing to breach a container.

TR: How do you integrate the tracking and sensor technologies?
FLYNN: When the sensor goes off, the location of the box should be logged, and then I want that information stored until the box gets to a point where I can act on it, like a loading port. There, it goes through an RFID interrogator that says, "A box is coming in, here's the box's data, and whoops, the sensor went off." We can find out just where that was. And then the terminal operator can say, "I don't want that box in here. Let's shift it off over to this—hopefully safer—area here, and then we'll go through and do an inspection."

TR: How much will all this technology cost?
FLYNN: Equipment that monitors the position and integrity of the cargo would likely cost from $100 to $200 per box. Built-in sensors that could detect chemical and radiological materials would add another $50. Affordable and dependable sensors for biological agents are probably still a couple of years away but will come in about that price as well. A container has a typical life span of 10 years and is used up to five times per year, so even if the final installation and maintenance price tag came in at $500, and the sensors were replaced every five years, the cost of the "smart box" technologies could be as low as $10 to $20 per use. To put that figure into context, transpacific freight rates have fluctuated by more than $1,000 per container over the past 18 months with no measurable impact on world trade.

TR: Couldn't the bad guys find a way around these technologies?
FLYNN: The bad guys who are sophisticated will compromise your system—block your sensor, jam the signal, they'll do all those things. But security works when you build layers. Each layer itself doesn't have to be perfect. But collectively they create a pretty powerful deterrent. And it'll get you to the point where these guys say, "This is not a system that I want to mess with," versus the one we have right now, which is practically an open invitation for terrorists to do their worst.

Born-Again Heart

BY CORIE LOK

Conventional wisdom holds that, with the exception of skin and blood cells, most tissues in the body do not normally regenerate. But recent research has uncovered some surprising biological mechanisms that indicate that the body does in fact have the potential to repair some other vital tissues. Hoping to exploit this work, a Harvard University and University of Utah startup, Hydra BioSciences, is seeking to develop drugs that it says will repair damage from heart attacks.

Hydra's focus is on heart attack survivors—a group joined by hundreds of thousands of people in the United States every year—who are often left with damaged, scarred cardiac tissue that could lead to complete heart failure later in life. Current drugs don't repair the tissue, so Hydra is working on new treatments that will nudge mature heart-muscle cells to multiply again and ultimately form new, beating muscle. The three-year-old company's first project is to develop drugs that would be given to patients within a few weeks after a heart attack to trigger regrowth of the healthy cells near the injured area and prevent the heart from weakening and scarring. A similar therapeutic strategy could eventually work for a wide range of ailments and injuries, such as type I diabetes, retinal degeneration, spinal-cord injury, and Parkinson's disease, says Mark Keating, Hydra's cofounder and a researcher at Children's Hospital Boston.

In January, Hydra raised almost $19 million in second-round venture financing. And it has also made progress on discovering drug candidates. It recently isolated a protein that may stimulate cell growth in the heart and hopes to begin testing it in animals by the beginning of next year. "If this works, we can regenerate the heart and create newer, younger, better cells," says Piero Anversa, director of the Cardiovascular Research Institute at the New York Medical College.

The company plans to eventually partner with a large pharmaceutical maker to take promising compounds through the various phases of clinical testing. If all goes well, however, market approval for even the company's most advanced drug candidates still remains at least five to seven years away.

Scientists have long dismissed the idea that the heart could grow new tissue after injury. One reason, they thought, was that contracting heart muscle cells are past the youthful stage in their life cycle when they are capable of dividing and replicating themselves. In the last few years, however, a few scientific papers have suggested that heart tissue has the potential to replenish itself in a number of different ways. Indeed, Keating suggests that even mature heart muscle cells can, under the right conditions, revert back to a youthful state and begin dividing again. Keating has found evidence for this in zebra fish—a favorite lab subject—and mouse muscle cells, though Hydra researchers have yet to show that the same thing can happen in living mammals.

Experts in the field are taking a wait-and-see attitude toward Hydra's approach. "The possibility is there to stimulate regeneration, provided that the drugs are cardiac-specific," says Loren Field, a cardiac biologist at the Indiana University School of Medicine.

Despite the unknowns, with more Americans suffering heart attacks every day, and with no treatments on the market that repair the damaged muscle, Hydra BioSciences is intent on turning the latest scientific findings about the mysteries of the human heart into novel and needed drugs.

HYDRA BIOSCIENCES

HEADQUARTERS: Cambridge, MA

UNIVERSITY: Harvard, University of Utah

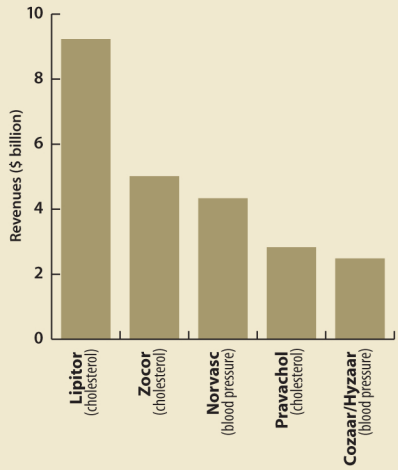
INVESTMENT RAISED: close to $30 million

LEAD INVESTORS: Lilly BioVentures, Polaris Venture Partners, Abingworth Management

KEY FOUNDERS: Mark Keating, David Clapham, Dean Li, Laurie Keating

CARDIAC BLOCKBUSTERS

Top-five-selling cardiovascular drugs worldwide for 2003



SOURCE: S. G. COWEN SECURITIES (BLOCKBUSTERS)

OTHER MENDERS OF BROKEN HEARTS

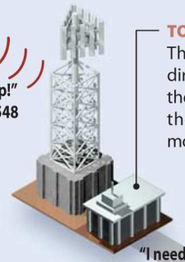
COMPANY	TECHNOLOGY
GenVec (Gaithersburg, MD)	Transplant of patient's own skeletal muscle cells into the heart
Geron (Menlo Park, CA)	Transplant of heart muscle cells derived from human embryonic stem cells
Sangamo BioSciences (Richmond, CA)	Engineered DNA-binding proteins to activate or repress genes involved in blood vessel formation and heart failure
Valentis (Burlingame, CA)	Gene therapy to stimulate new blood vessel growth for arterial disease

Wireless 911

Every year, more than 50 million 911 calls are made from mobile phones in the United States, according to the National Emergency Number Association. But unlike 911 calls placed from traceable landlines, wireless calls do not provide emergency call center operators with location information—a shortcoming that can hold up emergency responders. To avoid such delays, the FCC initiated a plan requiring wireless carriers to provide call centers with callers' geographic coordinates, their mobile-phone callback numbers, and the locations of the towers or antennas receiving their calls, by 2005. Experts estimate that it will take longer for the nearly 6,000 U.S. emergency call centers to upgrade their technology to accommodate the two methods of location tracking—handset-based assisted GPS and network-based tower location—used by wireless carriers. Here's how it will work. TEXT AND ART BY 5W INFOGRAPHIC

USER PLACES CALL
The signal, which carries the caller's voice and the mobile phone's callback number, is picked up by the closest tower or antenna.

"I need help!"
617-555-9548



TOWER OR ANTENNA
The tower or antenna directs the caller's voice, the phone number, and the tower's code to a mobile switching center.

MOBILE SWITCHING CENTER
The switching center simultaneously packages information about the call three different ways and directs the packages to three locations.

"I need help!"
617-555-9548
Tower 12N9G55

3571329416 "I need help!"

1 Assigns the signal a 10-digit routing number that uniquely identifies the caller and the tower code, then directs it and the voice signal to the appropriate local exchange carrier.

3571329416 617-555-9548

2 Passes the routing number and the callback number to a location information database.

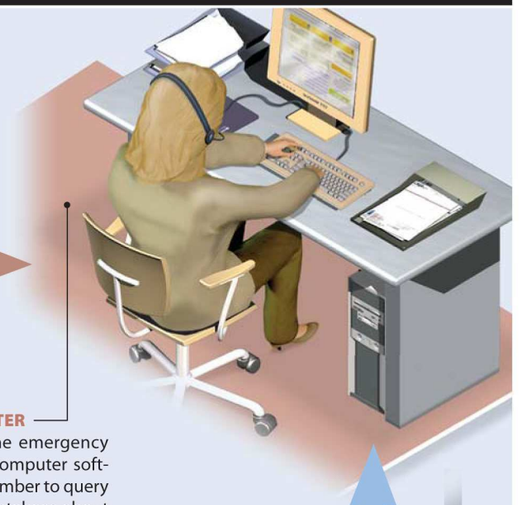
33.739 N, 84.388 W

3 Alerts a position-determining system that the call is an emergency and triggers the process of pinpointing the caller's location.

POSITION-DETERMINING SYSTEM
The position-determining system maintained by an independent contractor uses either GPS satellites or wireless communication towers to locate the caller, then forwards the geographic coordinates to a location information database.

LOCAL EXCHANGE CARRIER
Based on the routing number, the local landline phone company's 911 switch determines which emergency call center should receive the call, which it forwards along with the routing number.

3571329416 "I need help!"

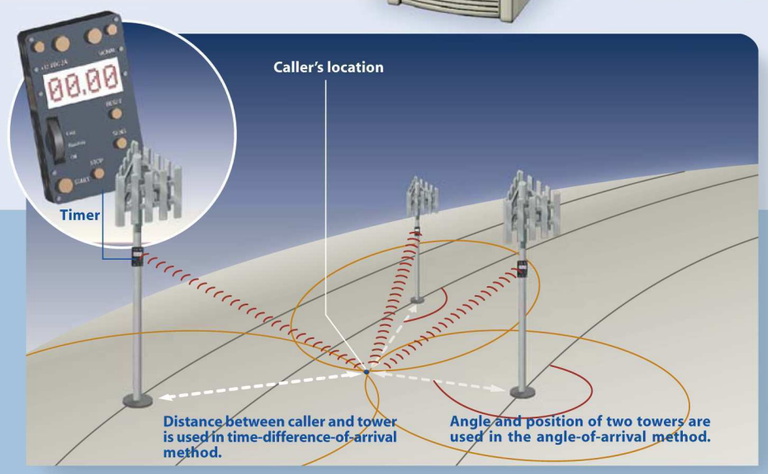


EMERGENCY CALL CENTER
An operator receives the emergency call on a phone, while computer software uses the routing number to query a location information database about the tower's address and the caller's geographic coordinates and callback number. Other software uses the geographic coordinates to map the caller's location.

3571329416
617-555-9548
Tower 12N9G55 = 30 Granite Avenue
33.739 N, 84.388 W = 125 Peachtree Street

LOCATION INFORMATION DATABASE
Upon receiving the information from the mobile switching center, the database creates a record file that will house all of the information associated with the routing number, including the caller's geographic coordinates, the tower location, and the callback number.

OPERATOR DISPATCHES HELP
With location information in hand, the operator dispatches emergency personnel to the caller.



Whether the position-determining system uses GPS satellites or wireless communication towers to determine the caller's location depends on the wireless carrier's infrastructure. If the system relies on GPS satellites, the process used is called "time difference of arrival." If the system uses cell-phone towers, it can either employ the time-difference-of-arrival method or an "angle of arrival" approach.

Time difference of arrival A timer on a tower or GPS satellite measures how long it takes to receive a phone's signal and uses that information to calculate the distance between the phone and the tower or satellite. But the phone can be anywhere on the perimeter of an imaginary circle (or sphere, in the case of the satellite) whose radius is that distance. Three towers or satellites listening for the signal can locate the caller at the point where their circles or spheres overlap.

Angle of arrival Direction-sensitive "smart" antennas determine the angle from which the phone's signal arrives at the tower. Using two or more angles and the positions of the towers, the system can calculate the caller's location.

SOURCES: BELLSOUTH, VERIZON WIRELESS, AND THE NATIONAL EMERGENCY NUMBER ASSOCIATION

Open Dating

MY LAB AT MIT PUBLISHES A CALENDAR OF EVENTS on its website. Lab staff can use the site to enter information about talks, seminars, and special events. Lab members can even sign up to get the day's announcements sent to them by e-mail. When I see a talk that looks interesting, I copy the announcement's text and paste it into my computer's calendar. ▪ The registrar's office at MIT publishes the institute's academic calendar. This calendar tracks official events, such as the start of classes, institute vacations, and thesis deadlines for grad students. At the beginning of the school year, I spent half an hour entering these dates into my computer as well.

My wife, Beth, has a calendar, too—this one filled with doctor appointments for the kids, my daughter's gymnastics lessons, and the nights that I have childcare duties. She keeps her calendar on her Mac with Apple's iCal program and occasionally e-mails me reminders about important appointments. But she doesn't have to: less than 15 minutes after she enters an appointment into her calendar, it automatically appears in mine.

Like the MIT calendars, Beth's is also published on a website. But instead of being published in a form that's easy for humans to understand, her complete calendar is uploaded every 15 minutes in a computer-readable form called iCalendar. My calendar program downloads this file every 15 minutes and displays Beth's calendar events in a different color on my own calendar. Likewise, my calendar events are automatically uploaded to the Web server, downloaded by Beth's copy of iCal, and displayed on her calendar.

Don't confuse Apple's iCal program with the iCalendar file format: iCal is an application for the latest Macintosh operating system, but iCalendar is a six-year-old open standard that was developed to let desktop applications share calendar events. An iCalendar file can consist of a single appointment, a repeating appointment, or items from a to-do list.

Those same engineers who developed iCalendar also created vCard, a kind of virtual business card used to store names, phone numbers, and other contact information. VCard has become the standard for moving that kind of information around the Internet; you probably have received hundreds of e-mail messages with vCards attached. With most e-mail programs, you can just click on these attachments and have them automatically added to your address book.

Every organization that has a website should publish a list of its upcoming events in the iCalendar format.

The iCalendar format has been decidedly less successful. One reason is that Microsoft has not embraced it; Outlook 2003 claims to support iCalendar, but the implementation is incomplete and doesn't work properly. But support for iCalendar is picking up steam. You can now create, display, and subscribe to iCalendar files over the Internet using either Mozilla Calendar or Ximian's Evolution; both of these open-source programs provide full support. A nifty Web-based application called PHP iCalendar displays these files directly on a website.

Tools like these, based on standards that are both open and easy to use, are incredibly powerful. I have set up a password-protected website with PHP iCalendar that lets a few trusted people access my entire calendar, with all of its confidential information. But I've written another program that can create a version of the calendar suitable for public viewing; in this "sanitized" calendar, descriptions of appointments and events are replaced by the word "busy." I publish this sanitized calendar on my website. It lets people know when I'm free for meetings but doesn't reveal any of my secrets.

All of these issues came to mind this spring when a bug in my lab's calendar notification system caused it to send multiple copies of each announcement to everybody in the lab. In the discussion that followed, it was clear that some people wanted one announcement sent out for each event, some wanted one daily message with all events, and some wanted reminders sent out 15 minutes before every talk. Finally some bright scientist (who happened to have a Mac) suggested that the lab simply publish the events in an iCalendar file; that way lab members could have the talks automatically displayed on their own calendars. It's a good idea—one that I hope will be taken up not just by the Computer Science and Artificial Intelligence Laboratory but also by the registrar's office and every other MIT organization that publishes a calendar. Publishing in iCalendar format makes it possible for people to subscribe and get updates automatically.

And let's not stop at MIT: every organization that has a website should publish its upcoming events in the iCalendar format. People could subscribe to whatever lists they wished and have the events automatically dropped into their calendars. If an organization starts publishing information that you find annoying, all you have to do is unsubscribe; the events will automatically disappear.

As with all open standards, the power of iCalendar is that it lets developers of different applications stop squabbling about file formats and spend their time delivering features to users. The sooner Microsoft and other companies selling proprietary calendar systems get on the bandwagon, the better. TR

Simson Garfinkel is an incurable gadgeteer, an entrepreneur, and the author of 12 books on information technology and its impact.

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The Lohner-Porsche, an early electric-turned-hybrid.

Prescient Porsche

The legendary car designer's earliest autos featured an innovation that took off 100 years later. **BY DAN CHO**

With major carmakers these days unveiling hybrid vehicles that combine the power of internal combustion with the efficiency of electric motors, it's natural to assume the technology is a recent twist on the electric car. The truth is that both electrics and hybrids trace their roots to the dawn of the auto industry. Skeptics who suspect that "environmentally friendly" cars must yield underwhelming performance may be surprised to learn that these vehicles were pioneered by a man whose name would become synonymous with sporty racers: Ferdinand Porsche. The renowned engineer's first car was an "electromobile," and it set the stage for hybrids today.

At the turn of the 20th century, before gasoline cars dominated transportation, they were detested for their noise and stinking fumes. Electrics were a quiet, odorless alternative, with a power source associated with modern wonders, thanks to inventors such as Thomas Edison. One young electricity buff was the mechanically precocious Porsche. Growing up in rural Austria, Porsche baffled his parents with his homegrown experiments with lamps and telephones.

At age 23, while working for an electrical-equipment firm, Porsche was recruited by Jakob Lohner, a carriage maker who had recently begun to dabble in automobiles. Porsche kicked off his auto career with an idea for simplifying the drive mechanisms of the day. He installed electric motors in each of a car's front wheel hubs, eliminating the shafts, gears, and chains needed for ordinary transmission systems. The Lohner-Porsche auto debuted at the 1900 Paris Exposition, taking the event's Grand Prix. Over the next couple years, Porsche would win both races and wide acclaim with his car.

But even before his automobile took center stage in Paris, Porsche recognized the weaknesses of electrics. The weight and limited storage capacity of the batteries severely restricted the cars' range. Still, Porsche didn't want to abandon the benefits of his hub-motor design. After the exposition, he designed a car that used an internal-combustion engine to drive a generator, which in turn supplied electricity to the two hub motors. This compromise solved the range problem, and the transmission system was still relatively quiet, smooth, and reliable.

Porsche incorporated his "mixed" propulsion into a few later vehicles, but it would be a century before manufacturers embraced the hybrid concept. TR

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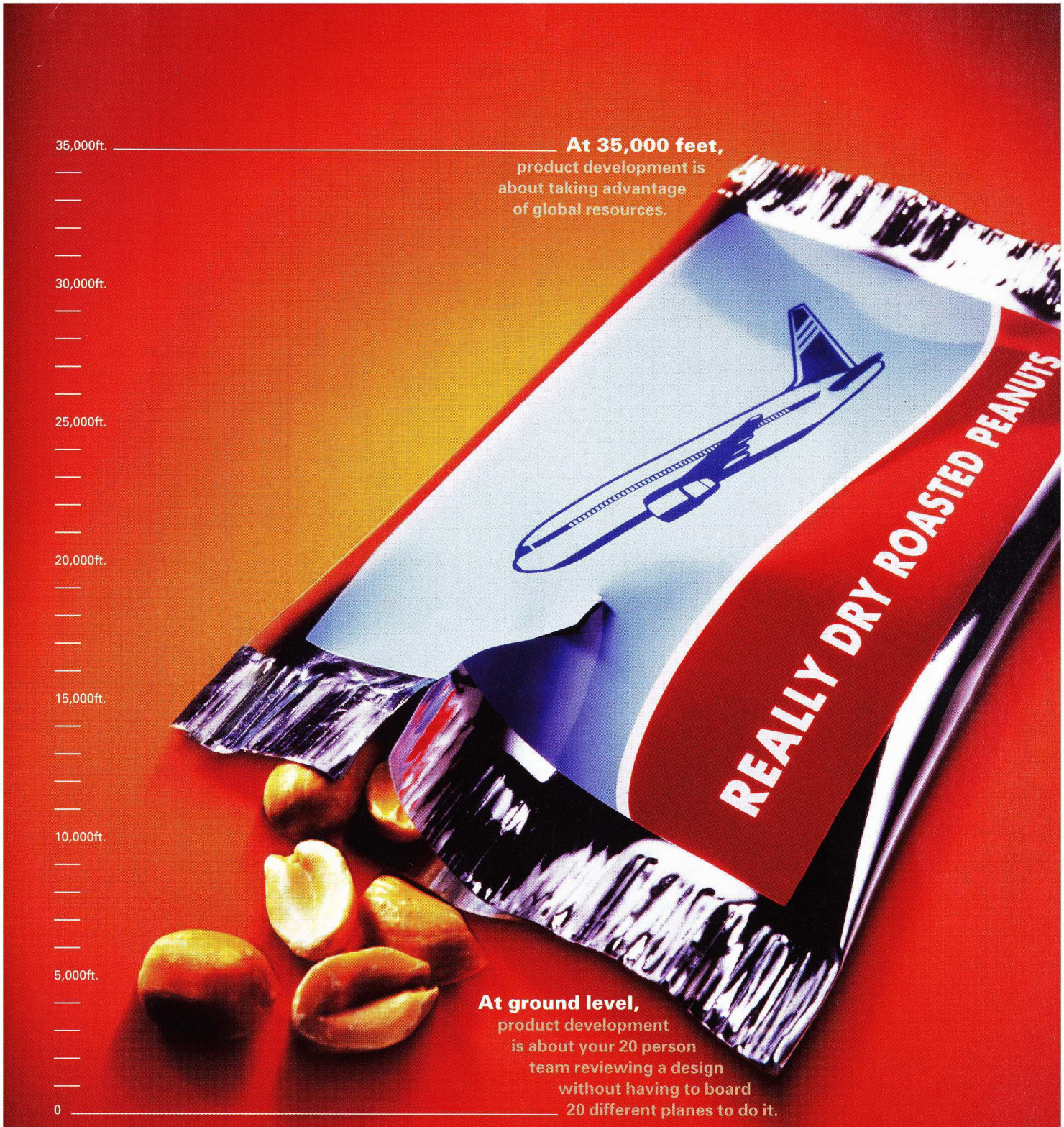

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